HOW **OXYGEN** COLORS THE UNIVERSE'S LIFE p. 28

25 TIPS TO PLAN YOUR 2017 **USA SOLAR ECLIPSE** p. 54

MARCH 2016

Astronomy®

The world's best-selling astronomy magazine

ACTUAL size of observable universe 10^{-32} second after Big Bang

NEW RESEARCH

The universe at actual size

Can inflation theory explain the cosmos? p. 22

How **Pluto** got its name p. 44

AND MORE

15 stellar software packages p. 49

Run a non-Messier marathon p. 58

Tele Vue's DeLite eyepieces p. 64

www.Astronomy.com

BONUS ONLINE CONTENT CODE p. 4

Vol. 44 · Issue 3

Online Content Code: ASY1603
Enter this code at: **www.astronomy.com/code**
to gain access to web-exclusive content

CONTENTS

22

MARCH 2016
VOL. 44, NO. 3

ASTRONOMY: DON DIXON

ON THE COVER

Scientists hope to explain what the cosmos was like just after its birth, when the entire universe was the size of a grapefruit.

FEATURES

COLUMNS

QUANTUM GRAVITY

IN EVERY ISSUE

Astronomy (ISSN 0091-6358, USPS 531-350) is published monthly by Kalmbach Publishing Co., 21027 Crossroads Circle, P. O. Box 1612, Waukesha, WI 53187–1612. Periodicals postage paid at Waukesha, WI, and additional offices. POSTMASTER: Send address changes to *Astronomy*, PO Box 62320, Tampa, FL 33662-2320. Canada Publication Mail Agreement #40010760.

ONLINE FAVORITES >>

Go to **www.Astronomy.com** for info on the biggest news and observing events, stunning photos, informative videos, and more.

Trips & Tours
Travel the world with the staff of *Astronomy*

Seasonal Observing
Find great targets in your spring sky

Ask Astro Archive
Answers to all your cosmic questions

Superstars of Astronomy
Interviews with top scientists

BY DAVID J. EICHER

Musings on element number 8

August 1774 was a big month for science. At Bowood House, Wiltshire, England, east of Bath and west of London, 41-year-old chemist Joseph Priestley discovered a "new air" in experiments that he later replicated with his fellow researcher Antoine Lavoisier in Paris. This "dephlogisticated air," referring to his now long-obsolete idea about combustion, turned out to be oxygen. Priestley, Lavoisier, and Swedish chemist Carl Wilhelm Scheele had a hand in its discovery and the realization of what it is. Lavoisier named the element after the Greek *oxys*, for "acid," and *gens*, for "creator."

In his story on page 28, Bob Berman describes the incredible importance of the periodic table's eighth element to the universe. The discovery of oxygen led to a chemical revolution, and we have long known how important the element is to life. It exists in the atmosphere as a gas, in water and other fluids as part of a liquid, and in rocks and minerals as part of a solid.

Oxygen is critically important because it is abundant and amazingly reactive. It forms water along with hydrogen (making H_2O incredibly plentiful on Earth), and lots of other substances that life relies on. Thanks to a large molecule called hemoglobin, oxygen, with every breath we take, travels from our lungs to cells that desperately need it for life's basic functions.

Its most common form, O_2, is a colorless, odorless, diatomic molecule. Forty-six percent of Earth's crust consists of oxygen, and it makes up some 21 percent of the planet's atmospheric volume.

As a very abundant element, oxygen can be measured as an indicator of star formation in the universe. Astronomers often measure oxygen abundances in young and old stars near us in the galaxy to constrain ideas about stellar evolution. They also observe oxygen in planetary nebulae and in the interstellar medium to understand the Milky Way's life history. And they measure it in other galaxies too — oxygen is all around!

On Earth, oxygen is used in a variety of processes all the time, but plants produce vast amounts of it via photosynthesis. The destruction of oxygen and its replenishment has happened at a nearly balanced rate for a long time, keeping the overall amount of available oxygen relatively flat.

Oxygen combines so readily with other elements that we call the process oxidation, and you can see the results of it nearly everywhere you look, from a rusty can to a peeled apple that soon turns disturbingly brown. The efficient reactions between oxygen and other elements create whole classes of minerals on Earth — chiefly oxides, which include things like hematite (iron oxide) — the same mineral that gives Mars its rusty-orange hue.

And lots of what is not yet oxidized one day will be. Oxygen is a major factor in our aging, in pushing us toward death. Free radicals in our bodies are unpaired oxygen atoms wreaking havoc on our cells. But it's more helpful than not: We need oxygen every second of our lives. Remember what you read in Bob's story every time you take in another cool, fresh breath.

Yours truly,

David J. Eicher
Editor

Follow the Dave's Universe blog:
www.Astronomy.com/davesuniverse
Follow Dave Eicher on Twitter: **@deicherstar**

Astronomy

Editor David J. Eicher
Art Director LuAnn Williams Belter

EDITORIAL
Senior Editors Michael E. Bakich, Richard Talcott
Associate Editors Eric Betz, Korey Haynes
Editorial Associate Valerie Penton

ART
Graphic Designer Kelly Katlaps
Illustrator Roen Kelly
Production Coordinator Jodi Jeranek

CONTRIBUTING EDITORS
Bob Berman, Adam Block, Glenn F. Chaple, Jr., Martin George, Tony Hallas, Phil Harrington, Jeff Hester, Liz Kruesi, Ray Jayawardhana, Alister Ling, Steve Nadis, Stephen James O'Meara, Tom Polakis, Martin Ratcliffe, Mike D. Reynolds, Sheldon Reynolds, Erika Rix, Raymond Shubinski

EDITORIAL ADVISORY BOARD
Buzz Aldrin, Marcia Bartusiak, Timothy Ferris, Alex Filippenko, Adam Frank, John S. Gallagher III, Daniel W. E. Green, William K. Hartmann, Paul Hodge, Anne L. Kinney, Edward Kolb, Stephen P. Maran, Brian May, S. Alan Stern, James Trefil

Kalmbach Publishing Co.
President Charles R. Croft
Vice President, Editorial Kevin P. Keefe
Senior Vice President, Sales & Marketing Daniel R. Lance
Vice President, Consumer Marketing Nicole McGuire
Editorial Director Diane M. Bacha
Corporate Art Director Maureen M. Schimmel
Art and Production Manager Michael Soliday
Corporate Advertising Director Ann E. Smith
Single Copy Specialist Kim Redmond

ADVERTISING DEPARTMENT
(888) 558-1544
Advertising Sales Manager Steve Meni
Advertising Sales Representative
Dina Johnston, djohnston@kalmbach.com
Ad Services Representative
Christa Burbank, ads@astronomy.com

RETAIL TRADE ORDERS AND INQUIRIES
Selling *Astronomy* magazine or products in your store:
Phone (800) 558-1544, Press 3
Outside U.S. and Canada (262) 796-8776, ext. 818
Fax (262) 798-6592
Email tss@kalmbach.com
Website www.Retailers.Kalmbach.com

CUSTOMER SALES AND SERVICE
Phone (800) 533-6644
Customer Service Astronomy@customersvc.com
Digital Astronomy.Digital@customersvc.com
Back Issues Astronomy.SingleCopy@customersvc.com

SPECIAL EMAIL ADDRESSES
Ad Sales adsales@astronomy.com
Ask Astro askastro@astronomy.com
Books books@astronomy.com
Letters letters@astronomy.com
Products products@astronomy.com
Reader Gallery readergallery@astronomy.com

Follow *Astronomy*

www.twitter.com/AstronomyMag
www.facebook.com/AstronomyMagazine
plus.google.com/+astronomymagazine

Alliance for Audited Media
KALMBACH PUBLISHING CO.
Please Recycle This Magazine

QG QUANTUM GRAVITY

EVERYTHING YOU NEED TO KNOW ABOUT THE UNIVERSE THIS MONTH . . .

HOT BYTES >>

TRENDING TO THE TOP

PEBBLE GAPS
Disk gaps around young stars can show where planets swept dust away, but a new study says they might show where hard-to-spot pebbles reside.

RAMBLE ON
In November, NASA'S Curiosity Mars rover rolled toward the Bagnold Dunes, which migrate as much as 3 feet (1 meter) per Earth year.

IT'S MAGNETIC
NASA's Voyager 1 appears to be in a distorted magnetic region just outside the solar system, which scientists expect it to leave by 2025.

SNAPSHOT

Galaxy fever

The search for island universes.

Nothing gets me going come springtime more than peering into an eyepiece at a distant galaxy. The knowledge that the photons striking my eye have traveled through space for millions of years is humbling. As is the realization of the sheer number of galaxies in the universe — now thought to be at least 100 billion.

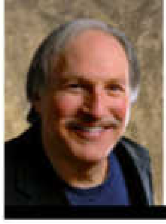
Our own Milky Way is, of course, visible to us only from within. But it appears in shape more or less like M83, a smaller version of the Milky Way, seen in this Hubble Space Telescope image. The light from M83's stars and gas has traveled through space for some 15 million years before reaching us, marking a time on Earth before the emergence of hominins, our earliest ancestors, who came into the scene some 6.5 million years ago.

The nature of galaxies varies incredibly, from stately spirals to barred spirals (like M83 and the Milky Way) to elliptical galaxies, great spheres of stars and gas. And there are irregular and peculiar galaxies, showing signs of galactic trauma or simply ill-organized masses of stars without distinct form.

Won't you join me in a round of galaxy fever this spring?

— David J. Eicher

Having discovered the nature of galaxies only 90 years ago, we now know that 100 billion or more exist in the cosmos and that some barred spirals, like M83 in Hydra, resemble our own Milky Way. NASA/ESA/HUBBLE HERITAGE TEAM (STScI/AURA) (M83); NASA/JPL-CALTECH/T. PYLE (SSC) (PEBBLE GAPS); NASA/JPL-CALTECH/MSSS (RAMBLE ON); NASA/JPL-CALTECH (IT'S MAGNETIC)



STRANGE**UNIVERSE**
BY BOB BERMAN

Strange indeed

When weirdness stalks astronomers.

Beware the Ides of March. Strangeness can envelop not just celestial objects, but astronomers, astronauts, and even amateurs. Odd events seem to befall those who choose to explore the universe, and I've collected many stories over the years. Consider: Not one but three different observatory directors have complained to me about having to clear away snakes that had built homes in the dome.

The weirdest thing that happened on the Moon was caused by Neil Armstrong disobeying his training. He failed to cut the lunar lander engine when the blue contact light came on 5 feet above the surface. He was just too good a pilot, and he flew so gently to the ground that the honeycombed aluminum legs, designed to crush and absorb some of the impact, remained intact. Result: The exterior ladder did not extend to the surface. Thus those first astronauts had to leap from the bottom rung.

Contrary to Armstrong's words, it was *not* "one small step." It was a giant leap. When Buzz Aldrin jumped off, the long fall broke the urine bag inside his boot. He had a live mic and didn't say anything, but his whole time on the surface was more like "one small *squish* for mankind."

Four years earlier, the Russians had their own bizarro experience when Alexei Leonov became the first to walk in space. The vacuum expanded his newly designed space suit far more than expected, and Leonov could not fit back in through the hatch. It wasn't even close. He also couldn't use his fingers because the inflated glove section had gotten too rigid. A nightmare. He was trapped outside with immobile fingers. Eventually, with his spacewalk double its scheduled length, he managed to release a lot of the suit's air, remain conscious, and squeeze through the opening. (The strangeness wasn't over. The onboard computer failed, and his craft landed 600 miles off-course in a mountainous wilderness. It took his rescuers two days to find him.)

Total eclipses have their own strange tales. I myself have witnessed superstitious nonobservers ducking indoors to hide from a total eclipse.

Eclipse expert Fred Espenak told me of a time in Africa when clouds started covering the Sun just as totality began. Improvising, he tore off at breakneck speed, and, staring upward while running, managed to keep the eclipsed Sun in a little hole.

"THE WEIRDEST THING THAT HAPPENED ON THE MOON WAS CAUSED BY NEIL ARMSTRONG DISOBEYING HIS TRAINING."

A professional solar researcher told a different eclipse story. During a Soviet totality when that government had set up an observing station on an island in Lake Baikal, he and another American overslept. The hotel never gave them their wake-up call. They missed the ferry. Despondent, they set up their instruments on the hotel roof and watched the eclipse there. Later, they learned that the temperature drop during the eclipse's partial phase produced a single giant cloud over the island. Nobody at the "ideal site" saw a thing. Only the late sleepers.

In 1971, the Indian government invited me to its largest observatory. The 40-inch telescope in the Himalayan foothills, which they'd equipped with a visual eyepiece for that night, was a lot of fun. But when a junior astronomer assigned to run the equipment for our session arrived, he was visibly shaken. A tiger had stalked him on the path from the nearest village. The previous year, a child had tragically been killed there. Now the animal was back — on the very night I was visiting. When the observing ended we all had to walk the inky, wooded, 2-mile path; we had no choice. It was uncomfortable and surreal.

Some years back, John Dobson came and spent a night. The Dobsonian mount inventor and father of sidewalk astronomy had a cantankerous nature and eventful life, but one idiosyncrasy stood out. His self-imposed poverty meant that he never wanted to stay at a motel. Instead, he'd sometimes sleep in his telescope. Yes, inside the tube.

A decade ago, I gave a talk for a wonderful group at the Connecticut Star Party, and the president kindly dropped me back at the local airport and drove away. The night was dark and spooky. The airport was now closed. That's when I saw that the gate was locked, with no "entry code" visible. My plane was on the other side. So your supposedly distinguished speaker in his sports jacket had to climb the high barbed-wire-tipped fence like a terrorist, hoping no patrol car would appear. In that post-9/11 era, they'd surely wonder what was in the attaché case I'd tossed over. They'd never guess a meteorite. It wasn't my favorite moment under Cassiopeia.

This really is a strange universe. Please send your own bizarre true story related to the cosmos, plus any verification. We'll publish the weirdest ones eventually.

Contact me about my strange universe by visiting **http://skymanbob.com.**

FROM OUR INBOX

A nice surprise

I just read Jeff Hester's short article on "Postmodernist airplanes" on p. 14 in the November issue. While being a neuroscientist and a professor, I am also an amateur astronomer. And so, just a short note: Your article made my Sunday. I never expected to find such a well organized, concise, and eloquent set of statements about science while looking for a good tip/tilt device for my telescope. Congratulations. **— Rodolfo Llinas,** New York

Science or science fiction?

In the September issue on p. 28, your article "Multiverses: Science or science fiction?" was great! It was well written — I couldn't put it down. I am with the skeptics who think many of the multiverse ideas are not even wrong. I base my skepticism not just on your article but on a number of other sources I have read. I cringe when popular media gives a pass to such unscientific speculation. **— John Boncek,** St. Louis

BROWSE THE "STRANGE UNIVERSE" ARCHIVE AT **www.Astronomy.com/Berman.**


Three exclusive tour packages!
America's Music Cities
Pacific Northwest & San Francisco
National Parks of the American West
Eclipse photo by Bert Halstead
Experience
AMERICA'S 2017 TOTAL SOLAR ECLIPSE
August 21, 2017
The most awe-inspiring celestial sight is coming to the U.S. for the first time in 26 years. Skywatchers across 12 states can experience darkness at midday as the Moon passes in front of the Sun in a total solar eclipse.
It's an event you don't want to miss, and TravelQuest International and Astronomy magazine are here to help you make the most of it with three exclusive tour packages that celebrate the many cultural treasures America has to offer.
Surrounding the August 21 total solar eclipse, you can:
• Enjoy jazz, blues, country, and rock 'n' roll in New Orleans, Nashville, and Memphis
• Experience the spectacular scenery of the Pacific Coast from Seattle to San Francisco
• Journey through the pristine forests and snowcapped mountains of the West's National Parks
CHOOSE AN ECLIPSE EXCURSION TODAY!
Visit www.astronomy.com/eclipsetours
TRAVELQUEST international
Astronomy magazine
P27011

EARLY BIRDS. Astronomers using Hubble's largest survey to date showed that galaxies in the early universe were more efficient at converting gas to stars than their current counterparts, possibly due to the more compact environments back then.

PHOBOS IS CRACKING UP

Mars may have a moon only for another 30 million to 50 million years — the blink of an eye, in astronomical terms. For many years, astronomers thought Phobos' grooves, first seen in images sent by the Viking spacecraft, were signs of asteroid impacts. But recent modeling, presented November 10 at the American Astronomical Society's Division for Planetary Sciences meeting, shows that instead they are "stretch marks" from Mars' persistent gravitational tug, and signs of the world's eventual destruction.

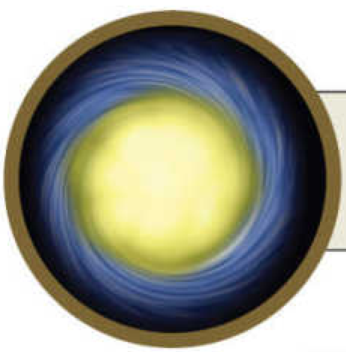
Mars and Phobos orbit closer than any other planet and moon in the solar system, at 3,700 miles (6,000 kilometers) apart, and they grow closer by 7 feet (2 meters) every century. Further, Phobos is unlikely to be a solid body, and is instead more likely a pile of rubble held together only loosely by its own gravity, surrounded by a powdery material a few hundred feet thick. As Mars pulls on Phobos' bulk innards, the outer layers adjust, flexing but still building stress. The grooves are the first signs of the surface fracturing, which will eventually break up the moon into many moonlets and perhaps one day a Saturn-like ring. — **Korey Haynes**

NASA/JPL-CALTECH/UNIVERSITY OF ARIZONA

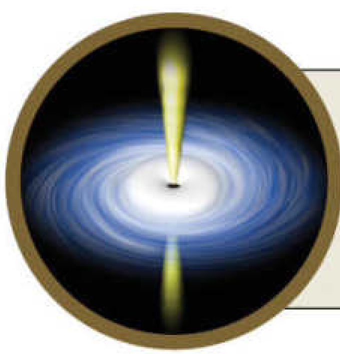
GROOVY. Astronomers now think the grooves on Phobos, first observed by the Viking spacecraft, are signs that Mars is slowly ripping its moon apart via tidal stressing.

NAMING BLACK HOLES

ALL ABOUT PERSPECTIVE. It took many years for astronomers to reconcile the disparate most luminous objects in the sky to the same source: active galactic nuclei (AGN), the actively feasting subset of supermassive black holes at the hearts of most galaxies. From different angles, these objects with their powerful central jets and surrounding doughnuts of dust and gas assume many different forms, and prompted just as many names. *ASTRONOMY*: ROEN KELLY AND KOREY HAYNES



Blazars appear head on, pointing jets directly at observers.



Quasars point at an angle, allowing some of their jets' high-energy beam to reach Earth. The more modest versions of this type are Seyfert 1 galaxies.

Radio galaxies align perpendicular to observers' line of sight, obscuring their AGN with a thick torus of dust and gas that absorbs most non-radio emission. Quieter versions with detectable galaxies are Seyfert 2 galaxies.

FAST FACT **Blazars can appear to shoot material at superluminal speeds, thanks to tricks of geometry.**

BRIEFCASE

SPACE DEBRIS PUTS ON FIERY SHOW

Human-made space debris came hurtling back to Earth on Friday, November 13, burning up harmlessly over the Indian Ocean. The object, designated WT1190F, was found by the Catalina Sky Survey in October and eventually turned out to be a temporary satellite that telescopes had also spotted in 2009 and 2013 before losing it. The debris was caught in a highly elliptical orbit that took it closer than Earth's geosynchronous satellites and then out past the Moon every few weeks. WT1190F burned up south of Sri Lanka almost exactly as scientists predicted, providing a valuable test of asteroid response readiness.

•

HEARTBEATS REVEAL A GALAXY'S AGE

Looking through an eyepiece at a galaxy like Messier 87 (M87), it's tough to imagine its brightness changing on human timescales. But many of its hundreds of billions of stars are late in their lives and swollen to an enormous size, like what will happen to the Sun when it eventually engulfs Earth. These stars pulse drastically, increasing and decreasing in brightness every few hundred days. Even such gargantuan stars can't be spotted over cosmic distances, but a team led by the Harvard-Smithsonian Center for Astrophysics took a long look at M87 for fluctuations in its overall brightness. The group's November 16 *Nature* paper found that 25 percent of pixels studied in Hubble images changed on average every 270 days. It showed M87 is about 10 billion years old. This heartbeat-measuring technique should help put more accurate ages to our neighbors. — **Eric Betz**

1.1 billion years

The time it took after the Big Bang for the first massive galaxies to appear.

NO DELIVERIES. Researchers studying primitive rocks from Canada found signs that Earth gained its water from accreting dust in the early solar system instead of a comet delivery service.

Hawaii Supreme Court revokes permit for massive telescope

On December 2, the Hawaii Supreme Court revoked the Thirty Meter Telescope (TMT) collaboration's permit to build on the summit of Mauna Kea. This is a decision that will set the $1.5 billion observatory's construction back months, if not years, while the collaboration begins the application process over again.

The Board of Land and Natural Resources originally granted the permit in 2011, with construction to have started in April of last year. Protestors and a stay by the Hawaii Supreme Court in November, however, effectively stopped all construction efforts.

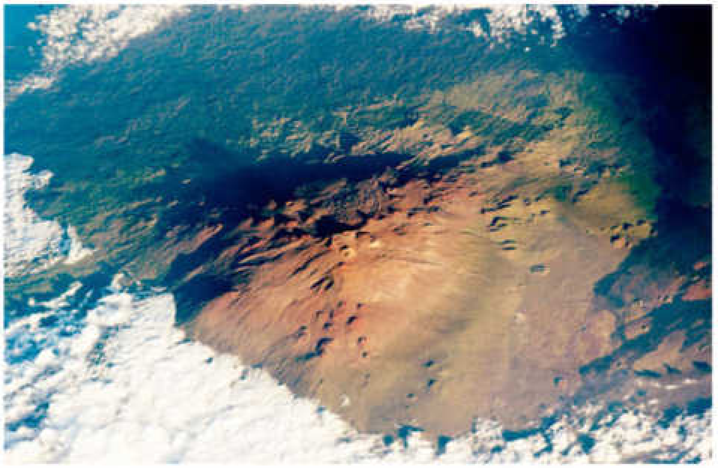
The court's December 2 decision hinged on the board's initial permit approval, which the court found violated due process. Protestors were granted the right to a contested hearing to argue their side, but the board approved TMT's permit to build before the hearing was held, prompting one justice to liken the events to a judge ruling before the trial occurs.

The court's ruling does not prohibit the collaboration from re-applying.

Opponents of TMT, mostly Native Hawaiians, have argued that the telescope would be a desecration of the mountain, which is sacred in Hawaiian tradition. Mauna Kea is one of the premier observing sites in the world due to its altitude, low light pollution, and stable air currents. In particular, TMT is intended as the Northern Hemisphere complement to equally large telescopes beginning construction in Chile: the Giant Magellan Telescope and the European Extremely Large Telescope.

The summit of Mauna Kea is already home to 13 observatories, several of which are slated for removal within the next few years. Part of the agreement to build on Mauna Kea has always been that the mountaintop be restored to its natural state upon completion of an observatory's use, and Native Hawaiians have grown increasingly vocal about the absence of such restoration thus far. The agreement to decommission the telescopes, as well as more severe limitations on future construction projects, is part of the ongoing discussion that has arisen because of the TMT controversy.

The TMT collaboration released a brief statement thanking the court for its timeliness and agreeing to abide by the ruling. Regarding the telescope's fate, it said only, "We are assessing our next steps on the way forward." — **K. H.**



THE PEAK OF OBSERVING. Hawaii's Mauna Kea, seen here from the International Space Station, holds great importance to both astronomers and Native Hawaiians. NASA EARTH OBSERVATORY

Tiny, stormy stars are bad news for habitability

Astronomers using the Atacama Large Millimeter/submillimeter Array in Chile observed a nearby red dwarf emitting flares 10,000 times brighter than the Sun's. Previous measurements by the Very Large Array likewise revealed the star's magnetic field to be hundreds of times stronger than the Sun's.

Astronomers have long considered red dwarfs to be excellent candidates for exoplanet hunting, since the stars are the most common type in the galaxy. But planets must orbit closely to the cool, dim stars to occupy a habitable zone warm enough for liquid water. If this star is representative of its type, red dwarfs' temper tantrums might render such zones dangerous places for life. The astronomers' research will appear in *The Astrophysical Journal*.

Corroborating evidence seems to come from studies of the Kepler-438 system, home to the most Earth-like exoplanet. The red dwarf host star emits powerful flares every few hundred days, each one 10 times stronger than the Sun's most violent outbursts. A planetary magnetic field might yet protect the vulnerable world. But in research slated to appear in *Monthly Notices of the Royal Astronomical Society*, scientists worry that coronal mass ejections, bursts of plasma that stars often spew alongside flares, could strip away a potential atmosphere, killing any chance at life on this Earth-like planet. — **K. H.**

TINY AND VIOLENT. The most Earth-like exoplanet, Kepler-438b, may in fact be highly irradiated, with its superflaring host star having long since stripped away its atmosphere via violent coronal mass ejections. MARK A. GARLICK/UNIVERSITY OF WARWICK

QUICK TAKES

DARK ENERGY KING
Dwarf galaxy Triangulum II contains only about 1,000 stars, but researchers observed them whipping around the galaxy's center at high speeds, implying a high proportion of dark matter — the highest of any known galaxy.

BABY PLANET
Protoplanet LkCa 15 b is the earliest directly observed planet still in the process of formation. Astronomers caught hydrogen gas falling onto the planet, heating, and lighting up. The planet resides inside a doughnutlike disk of material, and clears gaps as it grows.

GAMMA-RAY CYCLE
NASA's Fermi Gamma-ray Space Telescope captured regular variations in the output of an active galaxy over roughly two years, activity echoed in visible and radio wavelengths. If confirmed, it would mark the first gamma-ray cycle observed in a galaxy.

EARLY MONSTERS
The European Southern Observatory's VISTA telescope revealed to astronomers massive galaxies in the early universe that formed only 1.1 billion years after the Big Bang. This contradicts models that precluded such monster galaxies from forming so early.

LAPTOP LAB
NASA's Jet Propulsion Laboratory is developing a "chemical laptop" that could distinguish between biologically produced amino acids and those that form absent any living material; the lab is portable enough to travel on future rover missions.

COMET DUST
Astronomers combined MESSENGER data and modeling to find that dust from Comet Encke kicks up material from Mercury's surface whenever their paths cross. — **K. H.**

FOR**YOUR**CONSIDERATION

BY JEFF HESTER

That's astronomy, too

Seeking any port in a scientific storm.

A student needing science credits to graduate flips through the catalog. He considers biology for a moment, but that sounds squishy. Chemistry sounds smelly. Geology sounds … well, how much fun could rocks be? He doesn't even glance at physics.

That leaves astronomy. "Stars? I can do stars. Sign me up!"

The irony is that astronomy is physics, chemistry, geology, biology, and most other kinds of science you can think of. Throw in some history, politics, math, computer science, engineering, and philosophy for good measure. Astronomy is an any-port-in-a-storm science. Astronomers don't get to put a star in a laboratory where we can poke it and prod it under controlled conditions. We have to work with what nature gives us. Astronomy requires its devotees to be clever and to draw on absolutely everything that we know.

Humankind's historical conception of the universe was built on two pillars. The first was that Earth is the center of all things. The second was the belief that the heavens are *other*. From Hindus and Buddhists in the East to the Greeks in the West, our ancestors spoke of the four classical elements: earth, air, fire, and water. But there was a heavenly fifth element as well, described by Aristotle as unchanging and incorruptible. To this day we call the perfect example "quintessential," literally "made of the fifth element."

It is perhaps ironic that grasping the reality of the universe meant standing those traditional beliefs on their heads. We aren't the center. We are residents of an ordinary planet, orbiting an ordinary star in the disk of an ordinary spiral galaxy. And rather than other, the heavens are the *same*. The "principle" that terrestrial physics applies throughout the universe is actually a testable scientific theory. It is corroborated every time we observe familiar features in the spectrum of a distant galaxy or use computer models to build a virtual star with properties that match the real thing. The universal applicability of physical law is so ingrained today that we forget what a radical and world-changing idea it was.

That brings us back to that first day of class when, wearing a puckish smile, I would disavow students of the notion that by taking astronomy they had avoided all the hard stuff.

Physics is everywhere in astronomy. From the interaction of electromagnetic radiation with matter to the theories of space-time that describe the fabric of the universe, they don't call it astro*physics* for nothing! Likewise, interplanetary dust, molecular clouds, and the oxidation that gives Mars its red color are chemistry. Thoughts about extraterrestrial life are guided by what we know of terrestrial biology and evolution.

Comparative planetology is the cornerstone of modern planetary science. Starting with the geology, atmospheric physics, and chemistry of Earth, we look at other worlds and study how they are similar and how they are different. Comparative planetology is a two-way street. What we have learned from our sister worlds, along with the tools developed to explore them, has revolutionized the way we think about our own planet.

NASA/JPL/UNIVERSITY OF ARIZONA

Astronomy is not just telescopes and stargazing; scientists must use geology, physics, and chemistry to understand the data sent back by the many Mars missions.

You can't talk meaningfully about astronomy without grappling with historical, social, and philosophical currents like those present at the birth of the Renaissance. We revere Copernicus, Galileo, Newton, and others because their discoveries about the heavens changed the course of civilization.

Astronomy benefits from technology, but it also has driven innovation from the dawn of time. Imagine the new technologies needed to build Stonehenge! Physics was invented in large part to explain planetary motions. More recently you might know that Riccardo Giacconi won the 2002 Nobel Prize in Physics "for pioneering contributions to astrophysics, which have led to the discovery of cosmic X-ray sources." You might not know that X-ray astronomers are responsible for the technologies that form the heart of X-ray machines at airport security checkpoints and the CT scans that remade medicine.

Astronomy is mind-bendingly cool, but it's not comfortable. It demands that we change how we think about everything. To claim to know things about the distant universe, we have to carefully consider what knowledge is in the first place. We have to be willing to put even our most cherished notions on the chopping block. And we have to broaden our perspective. When Apollo 8 astronauts took the famous photo of Earth rising above the lunar horizon, it marked the first time human eyes saw our seemingly limitless and inexhaustible world as it truly is: a small, beautiful, fragile oasis adrift in space.

Astronomy is the study of the cosmos. If you run across something that is not part of the cosmos, be sure and let me know!

From time to time someone will ask me why an astronomer would spend so much time thinking about philosophy, history, evolution, climate science, cognition, and on down the list. I always give the same reply.

"Because that's astronomy, too."

Jeff Hester is a keynote speaker, coach, and astrophysicist. Follow his thoughts at **jeff-hester.com.**

BROWSE THE "FOR YOUR CONSIDERATION" ARCHIVE AT **www.Astronomy.com/Hester.**

MARS MISSION. The ExoMars 2016 spacecrafts finished testing in Europe in December and headed for Russia, where they will launch at the end of March.

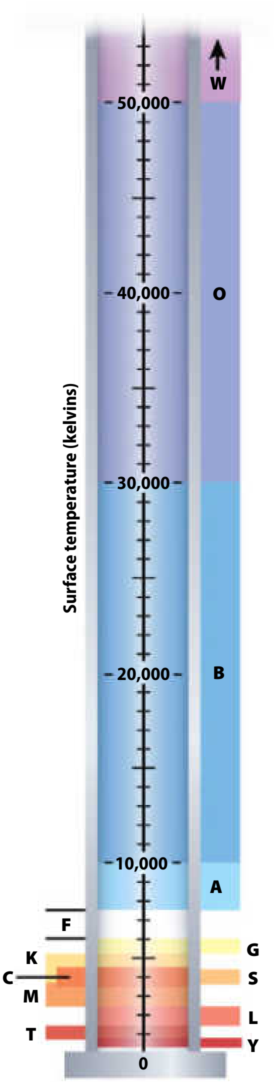
5,400 mph

(8,700 km/h)

The speed of winds directly measured on exoplanet HD 189733b.

ALPHABET SOUP

***S* IS FOR STARS.** Since the 1880s, astronomers have used Roman letters to classify the spectra of stars. This illustration shows where each of the current spectral classes falls according to temperature. *ASTRONOMY*: MICHAEL E. BAKICH AND ROEN KELLY



FAST FACT

An early spectral classification used the letters A through Q (except for N) in order.

New Horizons unleashes torrent of Pluto science

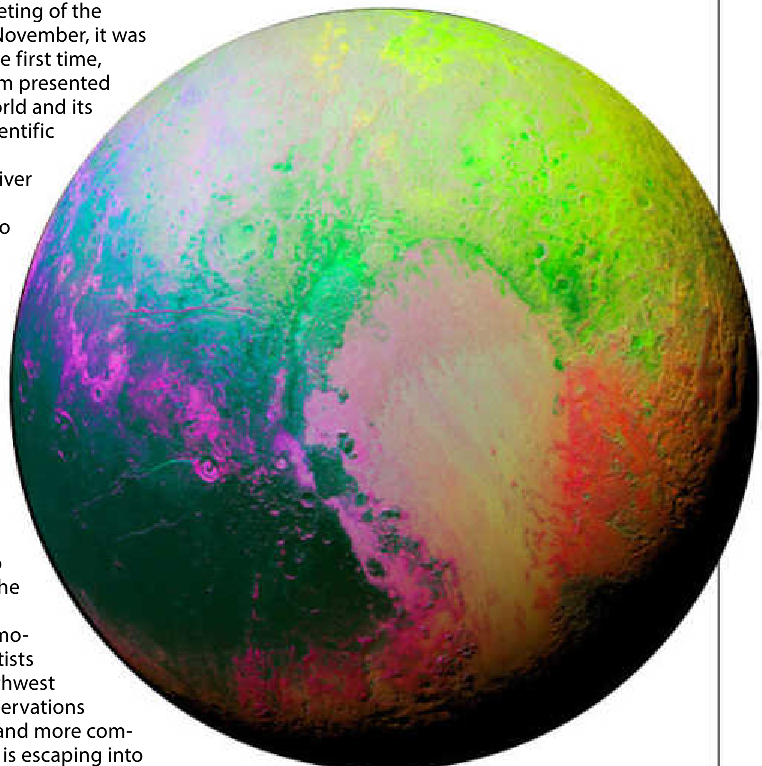
On day one of the 46th annual meeting of the Division for Planetary Sciences in November, it was almost all Pluto, all the time. For the first time, members of the New Horizons team presented their findings about the distant world and its family of moons to the broader scientific community.

New Horizons team member Oliver White of NASA's Ames Research Center delivered a bombshell: Pluto appears to have shield volcanoes, with broad bases, gentle slopes, and summit depressions (though no signs of ongoing eruptions). The features, informally named Piccard Mons and Wright Mons, rise 3.5 miles (5.6 kilometers) and 2 miles (3.2 kilometers) above the surrounding terrain, respectively. Of course, volcanoes on Pluto would be so-called cryovolcanoes, which erupt a slurry of melted ices and not molten rock. The outer solar system contains no other known shield volcanoes — the closest reside on Mars.

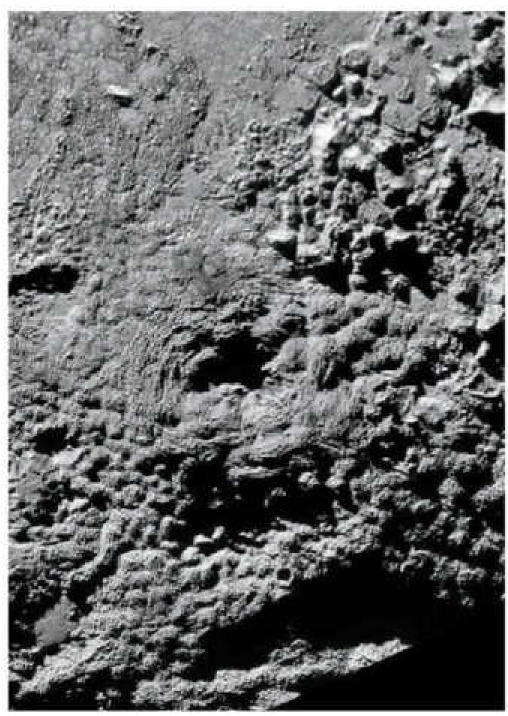
Above Pluto's surface lies an atmosphere totally unlike the one scientists expected. Leslie Young of the Southwest Research Institute reported on observations that show it is significantly colder and more compact than predicted, and little of it is escaping into space. Before New Horizons, team members thought that this blanket of nitrogen, which originates as nitrogen ice on the surface turning directly into gas, leaked into space at a rate that would have eroded away about a half-mile of the surface over the age of the solar system. The new escape rate places the loss at closer to a half-foot.

The small moons orbiting Pluto also present a host of new mysteries. First, all of them rotate faster than they revolve around the planet. (Most of the solar system's inner moons rotate and revolve around their planet at the same rate.) Hydra leads the way, completing 89 rotations for each revolution. Also, Nix now rotates about 10 percent faster than it did just three years ago. And both Hydra and Kerberos appear to be objects formed from the long-ago merger of two separate bodies — much like the comet 67P/Churyumov-Gerasimenko, which is currently under scrutiny by the European Space Agency's Rosetta spacecraft. New Horizons team member Mark Showalter of the SETI Institute summed up the wacky satellite system when he said that they "disobey our notions of how planetary moons ought to behave."

Finally, Southwest Research Institute scientist Alex Parker discussed the craters on Pluto. Each of these impact features formed when a small Kuiper Belt object (KBO) smashed into the planet. The more than 1,000 craters give scientists better statistics on the size distribution of KBOs than all of the known objects in the Kuiper Belt. The crater counts imply that KBOs formed relatively large (at tens of miles across) and not small as some researchers thought. This implies that the KBO cataloged as 2014 MU_{69}, the next target on New Horizons' itinerary if NASA approves an extended mission, should be a primordial object. Scientists would love to get a close look at one of these pristine solar system building blocks. **— Richard Talcott**



AN OUTLANDISH WORLD. This psychedelic image of Pluto uses false color to highlight more subtle color differences that could betray clues to the dwarf planet's geology. NASA/JHUAPL/SwRI



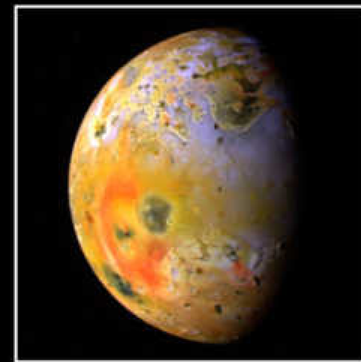
ICY VOLCANISM? Pluto's 90-mile-wide (150-kilometer) Wright Mons on the southern end of Sputnik Planum may be a hulking shield volcano like Hawaii's Mauna Loa or Mars' Olympus Mons. Instead of lava, it would erupt molten ice. NASA/JHUAPL/SwRI

SHIFTING HOT SPOTS ON JUPITER'S VOLCANO MOON IO

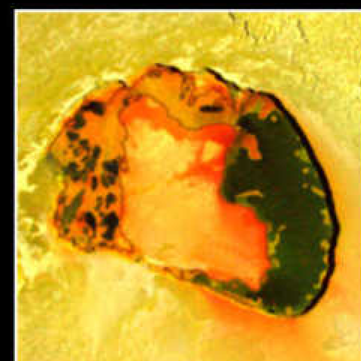
In 2015, a team of astronomers detected changes in one of Io's biggest volcanoes, Loki Patera. Team member Michael Skrutskie of the University of Virginia reported the discovery November 12 at the American Astronomical Society's Division for Planetary Sciences meeting.

The researchers observed Io with the Large Binocular Telescope (LBT), twin 8.4-meter mirrors on a single mount that together have the resolving power of a single 22.8-meter telescope. They viewed Io at an infrared wavelength of 4.8 micrometers, which is optimal for picking up volcanic heat signatures, on a night when its neighboring moon Europa passed directly in front.

Combined with the LBT's exquisite resolution, the occultation allowed the scientists to see details just 1 to 2 miles (2 to 3 kilometers) across. The observations revealed two separate hot spots within the 125-mile-wide (200km) lava lake that surrounds the volcano. Interestingly, the spots didn't match up with those the team saw in 2013, further proving Io's dynamic nature.
— R. T.

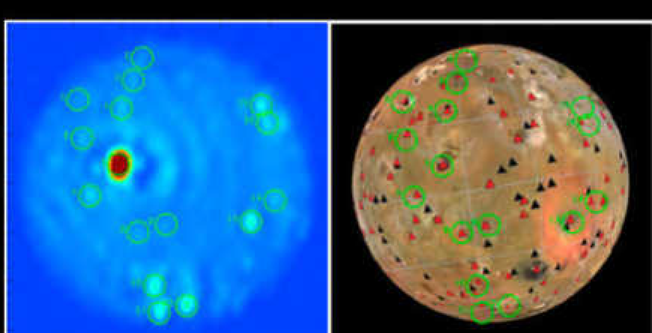


RING OF FIRE
The red ring circles active volcano Pele and indicates regions with high temperatures and recent surface changes.

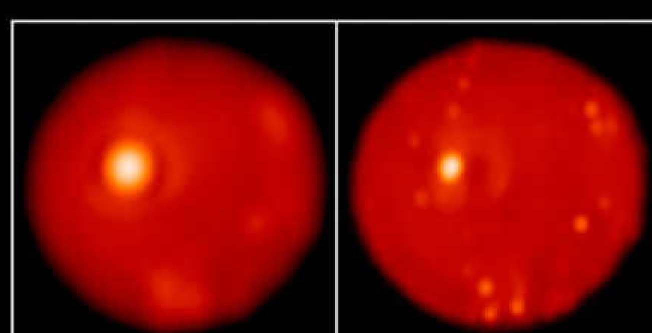


LOKI ISN'T ALONE
NASA's Galileo spacecraft snapped this nearly true-color view of volcanic region Tupan Patera in 2001, full of lava and sulfur.

CHAIN OF VOLCANOES
Tvashtar Catena showed off the gleam of hot new lava in 2000. The dark regions represent lava flows only a few months old.



MANY EYES
The Large Binocular Telescope spied Loki Patera's bright volcanic glow December 24, 2013 (left). A map compiled from NASA's Voyager 1 and 2 missions (acquired in 1979) as well as the Galileo orbiter (1995–2003), shows quieter activity.

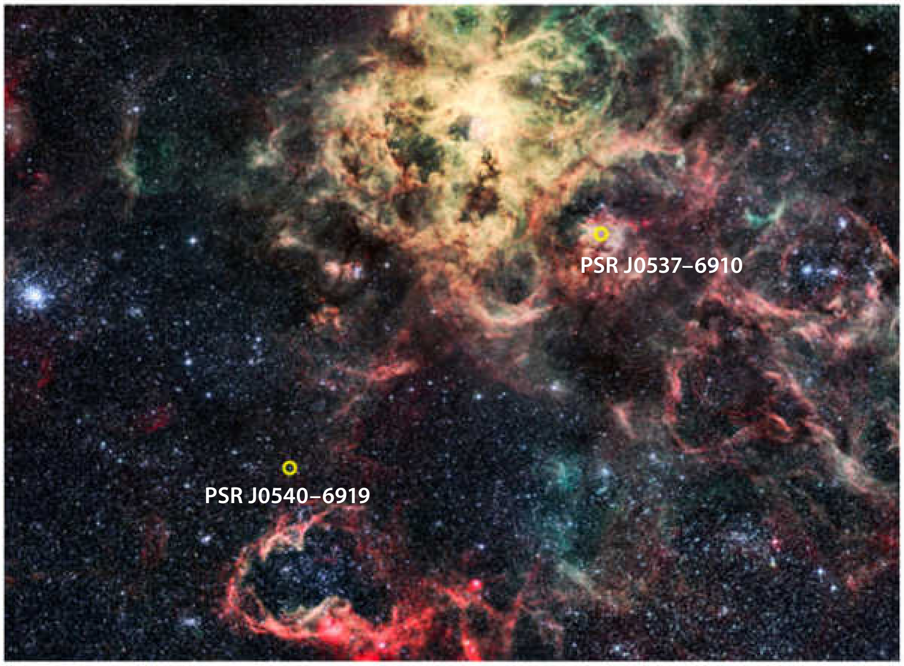


TWO IS BETTER THAN ONE
The Large Binocular Telescope (LBT) uses two 8.4-meter mirrors in a cooperative process called interferometry to achieve the resolution of a 22.8-meter telescope. A single mirror produces the image at left, but combined, LBT achieves the details at right.

NASA/JPL/UNIVERSITY OF ARIZONA (MAIN IMAGE, RING..., LOKI..., CHAIN...); LBTO-USGS (MANY EYES); LBTO (TWO IS BETTER...)

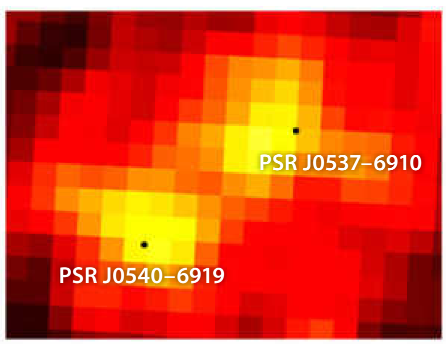
ASTRO**NEWS** **TWO OR NOT?** Astronomers found a new method to distinguish dual black holes in merged galaxies from rotating ionized gas.

Fermi's first extragalactic pulsar



NASA'S GODDARD SPACE FLIGHT CENTER; BACKGROUND: ESO/R. FOSBURY (ST-ECF)

PREMIER PULSAR. NASA's Fermi Gamma-ray Space Telescope has found the first gamma-ray pulsar outside our galaxy. PSR J0540–6919 is 163,000 light-years away in the Tarantula Nebula, an intense star-forming region home to the only supernova visible in Earth's skies since the invention of the telescope.



THE SKY IN GAMMA RAYS. The Fermi spacecraft shows the brighter pulsar J0540 produces most of the gamma rays coming from the Tarantula Nebula. NASA/DOE/FERMI LAT COLLABORATION

When Supernova 1987A popped up in southern skies February 23, 1987, it was the first such stellar explosion visible to the naked eye in centuries. And it's still providing new science and discoveries about core-collapse supernovae.

So, after NASA's Fermi Gamma-ray Space Telescope launched in 2008, astronomers hoped to use it to search the supernova's aftermath for a pulsar. When a star explodes, it can leave behind its core in the form of an ultra-dense neutron star that squeezes the mass of half a million Earths into a city-sized orb. This rapidly rotating and magnetized stellar remnant sends bursts of radio waves, gamma rays, X-rays, and even visible light toward our planet that let astronomers know it's a pulsar.

Gamma rays have the highest energy of any radiation. And early on, Fermi identified the Tarantula Nebula where SN 1987A took place as a bright gamma-ray region. Astronomers presumed the glow was coming from subatomic particles colliding in supernova shock waves. However, in a paper published November 13 in the journal *Science*, astronomers now say these gamma rays come from a totally unrelated pulsar.

This gamma-ray pulsar, cataloged as PSR J0540–6919, spins 20 times every second and is the brightest such object known. There is only one other known pulsar in the Tarantula Nebula, J0537-6910. Astronomers knew of the existence of both objects from earlier X-ray searches, but the strong gamma-ray radiation was unexpected.

"The gamma-ray pulses from J0540 have 20 times the intensity of the previous record-holder, the pulsar in the famous Crab Nebula, yet they have roughly similar levels of radio, optical and X-ray emission," said coauthor Lucas Guillemot. "Accounting for these differences will guide us to a better understanding of the extreme physics at work in young pulsars."

Before the mission, astronomers knew of just over a half-dozen gamma-ray pulsars. Fermi found 160. However, this one is the first known outside our galaxy, as the Tarantula Nebula lurks 163,000 light-years away in the Large Magellanic Cloud, a small satellite of our own Milky Way. — **E. B.**

1,000 **Gamma-ray bursts detected by NASA's Swift spacecraft.**

SECRET**SKY**

BY STEPHEN JAMES O'MEARA

A whale of a story

Here's a new way to look at the legend of Cetus.

On March 5, 2016, astronomers expect one of the night sky's most celebrated long-period variable stars, Mira (Omicron [o] Ceti), to rise to maximum brightness. The celestial leviathan now is beginning to slip beneath the western horizon after sunset. We can substitute these events for the mythical events discussed in this month's column, which asks you to consider scuttling the notion of Cetus as a whale and to look at this familiar legend in a different light.

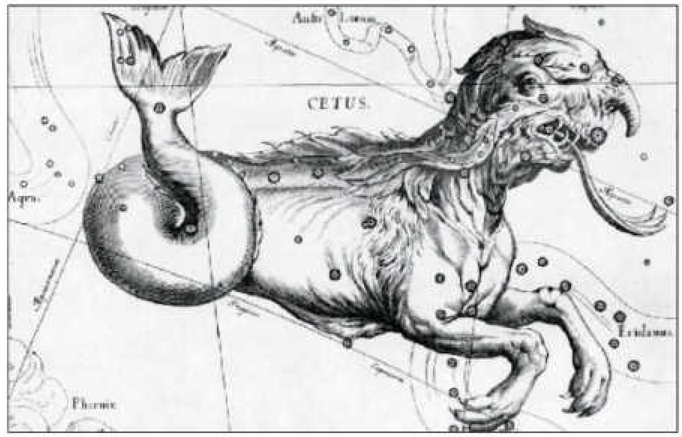
Terran inspiration?

Last October, Deborah Carter and I climbed Mount Chimaera in southern Turkey to see what Pliny the Elder referred to as "a flame that does not die by day or by night." As we watched this eternal fire (actually numerous pockets of methane that have been burning for some 2,500 years) with the stars of Cetus rising and Perseus and Pegasus flying, I saw what Stephen R. Wilk proposes in his book *Medusa: Solving the Mystery of the Gorgon* — that Cetus is the mythological chimera.

The poet Homer describes the chimera as being a "monster of divine origin," with a serpent's tail, a she-goat's body, and the head of a lion with fiery breath. Early sources also tell us that Mount Chimaera was likely the terrestrial inspiration for the Frankenstein-like appearance of this beast.

Celestial cartographers depicted it as Cetus — its tail signifying the snakes found on the mountain's lower slopes, its body symbolic of the goats on the mountain's midslopes, and its head representing the mountain lions that roam the summit where a fiery breath escapes as the eternal flame.

When Capt. Francis Beaufort, an associate of John Herschel and creator of the Beaufort wind scale, observed the eternal flames, he wrote that they came from an "aperture … shaped like the mouth of an oven." This terrestrial aperture resembles the irregular oval of stars that forms the head of the celestial chimera.



Cetus looks like some kind of Frankensteinian monster in this image from Johannes Hevelius' *Firmamentum Sobiescianum sive Uranographia, totum Coelum Stellatum*, which appeared in 1690. WIKIMEDIA COMMONS

Dual duties

If Cetus is the chimera, Wilk says, then Perseus doubles as Bellerophon, the hero who tamed Pegasus using Athena's golden bridle. He writes, "Flying on the winged steed … Bellerophon came upon the monster from above and peppered it with arrows. Finally, he shoved a lump of lead down its throat."

The chimera's fiery breath melted the lead, which blocked its air passage and suffocated the beast. The darts, Wilk contends, are the Perseid meteors, and the molten lead is the variable star Mira at maximum brightness in the beast's throat.

Another twist

In his *Fabulae*, a compilation of short myths and celestial genealogies written in the first century B.C., author Gaius Julius Hyginus tells us that

The eternal flames burn in Turkey's geothermically active region of Mount Chimaera. STEPHEN JAMES O'MEARA

Ceto (Cetus) is the mother of Medusa, whom Perseus beheaded. In many modern versions of the tale, Perseus then saves Andromeda from Cetus by holding up the head of Medusa and turning the leviathan to stone. So, in this version, Perseus kills both mother and daughter.

The first-century Roman poet Marcus Manilius, however, has Perseus engaged in a more savage battle with Cetus, as told in his *Astronomica*: "Hereupon … Perseus flies upwards and from the skies hurls himself at the foe … At last, its frame riddled with stabs, the beast sinks, returns once more to the surface, and covers the mighty ocean with its massive corpse."

Is Mira the fatal stab wound in the creature's neck? Could the beast's sinking and rising from the sea mirror the variable star's actions? As you watch Mira rise and fade this season (as the Whale sinks beneath the surface of the western horizon), give thought to these questions and send your conclusions to sjomeara31@gmail.com.

COSMIC WORLD

A look at the best and the worst that astronomy and space science have to offer. **by Eric Betz**

Cold as space — **Supernova hot**

Red station

The Night Wolves, Vladimir Putin's favorite biker gang, which fought in Crimea and Ukraine, get cosmonaut Sergei Volkov to put their flag on the ISS. Next up: Annexing space.

Scrap saved

An Alabama junkyard owner saves a rare Apollo lunar rover prototype driven by Wernher von Braun after he identifies it in his scrap. The opportunistic owner says NASA can have it back — for a price.

Far-off planet?

President Barack Obama highlights the first Earth-like planet found "in a distant galaxy" during Astronomy Night at the White House. Those spy satellites sure are advancing fast.

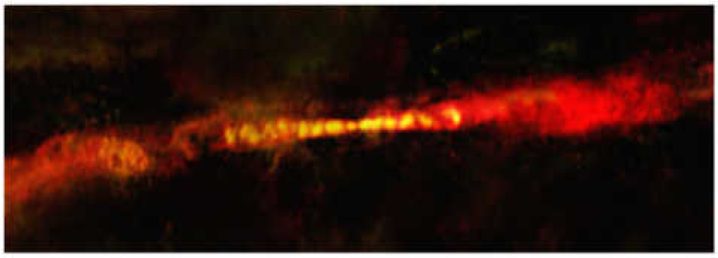
Alien flavors

Scottish whiskey maker Ardbeg tastes its ISS-distilled samples to find pungent and intense flavors, with hints of "antiseptic lozenges and rubbery smoke." So much for civilizing space.

@HIRURG_WOLVES/TWITTER (RED STATION); NASA (SCRAP SAVED); CHUCK KENNEDY (FAR-OFF PLANET?); NANORACKS, LLC (ALIEN FLAVORS)

BROWSE THE "SECRET SKY" ARCHIVE AT **www.Astronomy.com/OMeara.**

ASTEROID CRASH. Astronomers showed that a short-lived tail observed on asteroid 493 Griseldis indicates that it collided with another object in March 2015.



Protostar growth spurt

FITS AND STARTS. Astronomers published November 5 in *Nature* that they observed 22 distinct events in the growth of protostar CARMA-7 with the Atacama Large Millimeter/submillimeter Array. Protostars toss away some material even as they accrete and grow, and these outflows are easier to observe and measure than the material they ingest, but still inform astronomers about the rate of growth. The gaps in the outflow seen shooting away from CARMA-7 tell researchers that such growth is not steady, but bursty. — **K. H.**

B. SAXTON (NRAO/AUI/NSF)/A. PLUNKETT ET AL./ALMA/NRAO/ESO/NAOJ

Scientist seeks new definition of planet

The International Astronomical Union (IAU) created a ruckus in 2006 when it issued a new (actually, the first) definition of what a planet is. Pluto was relegated to a new category — "dwarf planet." At the 46th annual meeting of the Division for Planetary Sciences in National Harbor, Maryland, Jean-Luc Margot of UCLA described his efforts to create a better definition.

The IAU says a planet is an object that orbits the Sun, has enough mass that self-gravity forces it to take on a nearly round shape, and has cleared the neighborhood around its orbit. But the definition is neither quantitative nor general. It can't be applied to the thousands of known exoplanets.

Margot seeks to generalize the definition by defining a planet as an object in orbit around one or more stars or stellar remnants, has a mass large enough to clear its orbit (though he prefers the term "dynamically dominates"), and has a mass less than 13 Jupiter masses (to rule out brown dwarfs). He even defines what it takes for a planet to dynamically dominate its neighborhood based on its mass, the mass of the star it orbits, and its orbital radius or period — values easy to determine for the thousands of exoplanets discovered by the Kepler Space Telescope. Any planet that meets the mass limit also will be round, so there's no need to add a condition for that.

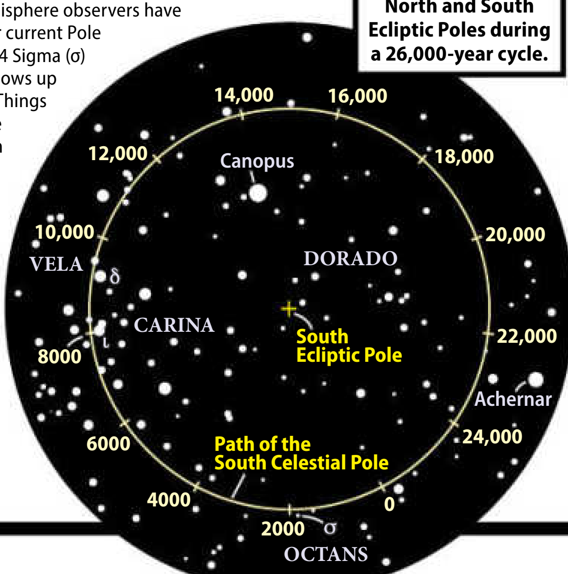
Margot's definition would grant planetary status to 99 percent of the Kepler objects but, alas, still keep Pluto on the outside looking in. — **R. T.**

WHERE'S THE SOUTH STAR?

TOWARD A BETTER FUTURE. The 2nd-magnitude star Polaris currently lies within 1° of the North Celestial Pole. But Southern Hemisphere observers have no such luck. Their current Pole Star, magnitude 5.4 Sigma (σ) Octantis, barely shows up to the naked eye. Things will improve in the future, however. In A.D. 8000, the pole sits within 1° of magnitude 2.3 Iota (ι) Carinae, and about 1,000 years later, it lies a similar distance from magnitude 2.0 Delta (δ) Velorum.

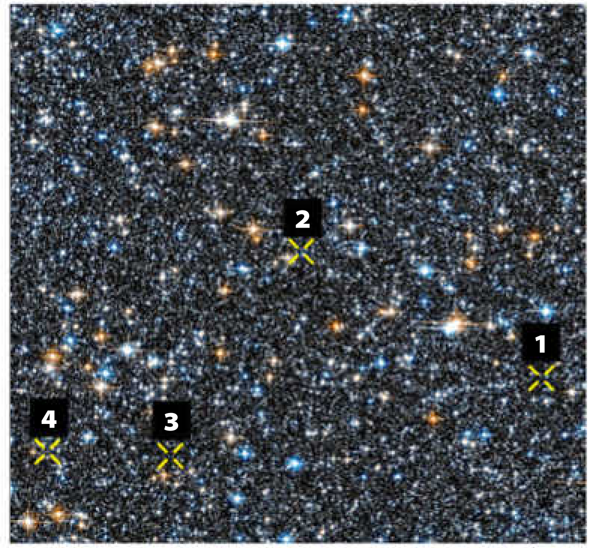
FAST FACT

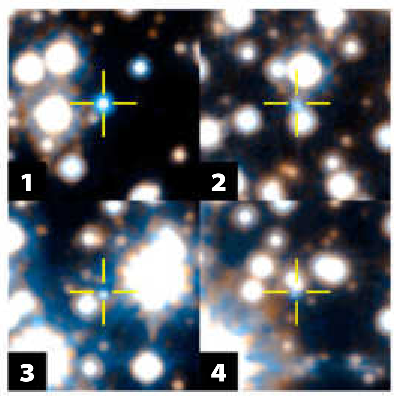
Precession causes Earth's axis to sweep out a 23.4° circle centered on the North and South Ecliptic Poles during a 26,000-year cycle.



ASTRONOMY: RICHARD TALCOTT AND ROEN KELLY

Milky Way's first stars shine in new Hubble view





SETTLERS OF SAGITTARIUS. Hubble took a deep look at the Milky Way's galactic bulge in search of the brightest white dwarfs — the embers of dead stars. These ancient stars are all that's left of our galaxy's first settlers. NASA/ESA/A. CALAMIDA AND K. SAHU (STSCI)/THE SWEEPS SCIENCE TEAM (SWEEPS FIELD)

Our galaxy is caught in a constant cycle of birth, death, and rebirth. And when stars face their cataclysmic ends, they can leave behind a smoldering core called a white dwarf. Just a teaspoonful of one of these Earth-sized stars weighs some 15 tons.

A team of astronomers led by the Space Telescope Science Institute (STScI) used the Hubble Space Telescope to take a deep look for these faint white dwarfs in the Milky Way's central bulge. And, as expected, the ancient stars showed the team a blueprint for how our galaxy was built.

Their survey of the 70 hottest white dwarfs required snapping images of the central bulge a decade apart and then subtracting the nearby foreground stars by identifying their faster motion.

The bulge is the Milky Way's dense, star-rich center. And the Hubble data back up the idea that it formed first, taking less than 2 billion years. Our Sun sits out in the surrounding suburbs of the galaxy's relatively flat disk, where the second and third generations of stars formed.

Astronomers say understanding these faint stars close to home can also shed light on the formation of distant galaxies, where it's not possible to pick out white dwarfs.

"These 70 white dwarfs represent the peak of the iceberg," says STScI's Kailash Sahu, who led the study. "We estimate that the total number of white dwarfs is about 100,000 in this tiny Hubble view of the bulge. Future telescopes, such as NASA's James Webb Space Telescope, will allow us to count almost all of the stars in the bulge down to the faintest ones, which today's telescopes, even Hubble, cannot see." — **E. B.**

OBSERVING**BASICS**

BY GLENN CHAPLE

Run a double star marathon

Messier and non-Messier marathons run? Next, capture these 109 great binaries in one night.

Attention, double star observers. Are you tired of sitting on the sidelines while your faint-fuzzy-seeking contemporaries participate in a Messier marathon? It's no fun being benched while these cluster-clutching, nebula-nabbing, galaxy-grabbing gluttons enjoy their deep-sky holiday. Take heart, my binary-bagging buddies. We now have a celestial marathon of our own!

But first, let me backtrack a bit. The Messier marathon is a noble activity — a true rite of passage for the backyard astronomer. It combines a tour of some of the finest deep-sky sights with a trip back in time to the galaxies of the Coma-Virgo Cluster, nearly 60 million light-years away. If you haven't already "run" a Messier marathon, I urge you to give it a try. Or check out Michael Bakich's "Run a non-Messier marathon" on p. 58. If you seek something different, the double star marathon is now an option.

I'm not the first to come up with the idea. Four years ago, Matt Wedel, assistant professor of anatomy at Western University of Health Sciences in Pomona, California, and the author of the must-read astroblog "10 Minute Astronomy" (www.10minuteastronomy.wordpress.com), proposed the idea. Plotting the 100 entries in the Astronomical League's (AL) double star program onto a sky chart, he noticed that 99 of them followed the distribution of the Messier objects and, therefore, could be captured during a Messier marathon.

Because the Messier marathon includes 109 deep-sky objects — a reasonable number of targets for an all-night session — I thought a marathon devoted to double stars should match that list. Because there is no double star catalog with a similar number of entries, I took Wedel's lead and began with the AL list (www.astroleague.org/files/obsclubs/DblStar/dblstar2.pdf).

I eliminated pairs in the atmospherically turbulent "twilight zones" (western evening and eastern morning skies), dropped a few wide ones, and then added noteworthy doubles not on the AL list. For these extras, I consulted the Saguaro Astronomy Club's list of the best double stars (www.saguaroastro.org/content/BEST-MULTIPLE-STARS.htm) and the "Table of Coloured Double Stars" in the Royal Astronomical Society of Canada's *Observer's Handbook*.

Small-scope observers will appreciate the fact that virtually all of these marathon doubles can be split with a 2.4-inch scope and a magnification of 100x. In fact, I've notched each with a 3-inch f/10 reflector using powers of 60x and 120x.

The two observing windows of opportunity for this year's Messier marathon are March 12/13 and April 2/3, weekends

Ras Algethi (Alpha [α] Herculis) is a binary you'll encounter in the Double Star marathon. It boasts an orange primary and an apparently olive green companion 4.7" away. DIETMAR HAGER

when the Moon lies near its new phase. Because the visibility of double stars isn't as affected by lunar phase as is that of the fainter Messier objects, we can extend these windows a few evenings before and after the above dates. There is a caveat, however.

"In a Messier marathon," Wedel notes, "the seeing isn't that crucial because you're observing big, extended objects, and just trying to log them, not necessarily tease out details. But to split some of the tighter double stars requires reasonably good seeing, and there's no way to predict that in advance, sometimes not even from early evening to midnight or midnight to dawn. So the Messier marathon has a tighter constraint from the Moon, but it's predictable, whereas the one sky condition that could make or break a double star marathon can't be predicted in advance."

When Messier compiled his catalog, it wasn't to showcase the finest deep-sky objects. He simply wanted to note the locations of the hazy-looking sky objects that kept tripping him up during comet searches.

The roster for the double star marathon, on the other hand, was purposely created to spotlight the finest stellar partnerships visible this time of year. It's certainly subject to second-guessing.

This is where you come in. No one, me included, has yet attempted the double star marathon. This is a trial run. Unlike the Messier marathon, a list pretty much etched in stone, I'm willing to tweak this one. If you're blessed with a pioneering spirit and would like to give the double star marathon a try, drop me an email and I'll send you the list (in Word format). Once you're done, email me a report that includes the number you observed and suggestions (if any) for changes. I'll publish the results next year.

Questions, comments, or suggestions? Email me at gchaple@hotmail.com. Next month: A showpiece binary star and a hidden diamond. Clear Skies!

FROM OUR INBOX

Seeing double

As an avid visual astronomer, I love viewing double stars. I enjoyed your article "Double trouble" on p. 18 in the November issue. One of my favorite doubles is an easy one: Schedar, the brightest star in Cassiopeia. The main star is brilliant gold with a purple companion, at least to my eyes. It can be difficult to see due to the glare of the main star — a dark sky definitely helps — but I see purple, which makes for a fantastic double.

Thanks as always for your wonderful articles that keep me coming back to *Astronomy* magazine. **— Michael Cefola,** Scarsdale, New York

We welcome your comments at Astronomy *Letters, P. O. Box 1612, Waukesha, WI 53187; or email to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

BROWSE THE "OBSERVING BASICS" ARCHIVE AT **www.Astronomy.com/Chaple.**

 CLOUD MODELS. Astronomers modeled 3-D clouds on GJ 1214b to explain how the exoplanet blocks light high in its atmosphere, stymieing efforts to understand what it is made of.

MAVEN sees solar wind strip Mars gases

Since the dawn of the Space Age, one of NASA's top missions has been figuring out how Mars went from warm and wet to cold and dry, and the agency took another step toward an answer in 2015. Last March, a string of solar storms smacked Mars, and astronomers used NASA's MAVEN spacecraft to watch as ions shot into space, never to return.

The solar wind consists of protons and electrons traveling at more than a million miles an hour, and it carries an electric field with it. It's this field that mixes with Mars' ions — charged gas particles.

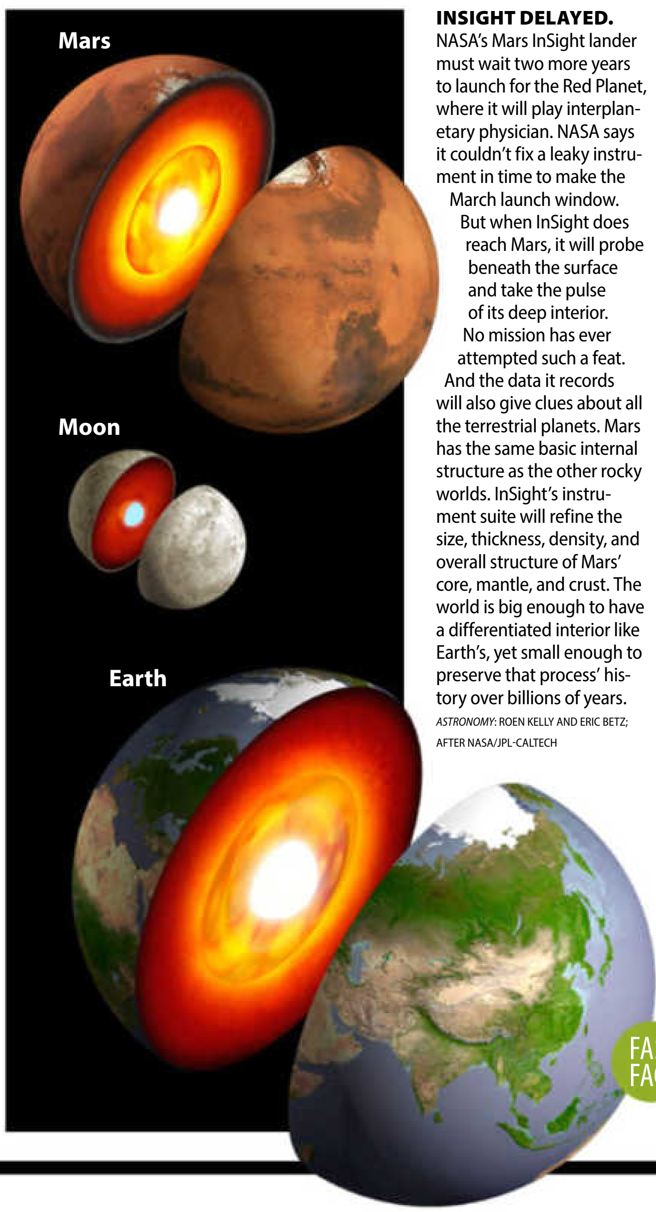
Every day, roughly 220 pounds (100 kilograms) of the Red Planet's atmospheric gas gets stripped away by the solar wind, according to MAVEN results published in November.

But that number increases dramatically during solar storms. Scientists say this loss played a major role in robbing Mars of its atmosphere — and eventually its water — over billions of years.

"Like the theft of a few coins from a cash register every day, the loss becomes significant over time," says MAVEN Principal Investigator Bruce Jakosky. — **E. B.**

PULVERIZED PLANET. Solar storms strip Mars' upper atmosphere of ions in this artist's rendering. NASA/GSFC

HOW DO PLANETS FORM?



INSIGHT DELAYED. NASA's Mars InSight lander must wait two more years to launch for the Red Planet, where it will play interplanetary physician. NASA says it couldn't fix a leaky instrument in time to make the March launch window.

But when InSight does reach Mars, it will probe beneath the surface and take the pulse of its deep interior. No mission has ever attempted such a feat. And the data it records will also give clues about all the terrestrial planets. Mars has the same basic internal structure as the other rocky worlds. InSight's instrument suite will refine the size, thickness, density, and overall structure of Mars' core, mantle, and crust. The world is big enough to have a differentiated interior like Earth's, yet small enough to preserve that process' history over billions of years.

ASTRONOMY: ROEN KELLY AND ERIC BETZ; AFTER NASA/JPL-CALTECH

Astronomers look to Titan for clouds, haze, and E.T.

On November 11 at the American Astronomical Society's Division for Planetary Sciences meeting, Carrie Anderson of NASA's Goddard Space Flight Center reported on her discovery of a new cloud feature above the south pole of Saturn's largest moon, Titan, similar to one captured in 2012 by the Cassini spacecraft.

Using Cassini's Composite Infrared Spectrometer, she found a much larger cloud system some 95 to 125 miles (150 to 200 km) above the south pole. This is the first time the probe has been able to observe winter's onset. (Saturn takes 29.5 years to orbit the Sun, so winter in the northern hemisphere was wrapping up when Cassini arrived back in 2004.) The clouds Anderson sees now are both higher and more extensive than those from 2004, leading her to conclude that winter on Titan "comes in like a lion and goes out like a lamb."

Titan has the thickest haze of any object in the solar system — at least today. Giada Arney of the University of Washington laid out the case for a hazy Earth during the Archean Era, about 4 billion to 2.5 billion years ago. Large quantities of methane arising from both geologic processes and bacteria drove the haze. As astronomers hunt for Earth-like exoplanets, what era on Earth should we be talking about?

POLAR VORTEX. The cloud system hovering above Titan's south pole is a warning that winter is coming. NASA/JPL-CALTECH/SSI

A haze-shrouded world rich in methane could be as full of life as one with a clear oxygen-rich atmosphere — and the hazy one would be easier to discern from light-years away. But how could we tell an exo-Earth from an exo-Titan? Arney says the ratio of methane to carbon dioxide would settle the question, with Earth-like worlds showing a smaller ratio. So perhaps as we scour the cosmos for extraterrestrial life, we should look for a pale orange dot instead of a pale blue dot. — **R. T.**

FAST FACT

The InSight lander will deploy a "mole," called HP³, to burrow 16 feet (5 meters) below the martian surface and create a temperature profile that will tell scientists how much heat the Red Planet is losing.

The race to COSMIC DAWN

Inflation stands at the heart of modern cosmology. So why haven't astronomers seen any signs of it? **by Eric Betz**

Alan Guth walked the aisles of a Massachusetts Institute of Technology auditorium pouring sparkling cider into giddy cosmologists' glasses. Then, he and Andrei Linde, the founding fathers of inflation, raised their hands high for a toast to the power of science. Their once wild theory now had physical proof. And a Nobel Prize seemed sure to follow. "Space Ripples Reveal Big Bang's Smoking Gun," declared *The New York Times* front page on March 18, 2014. Harvard, Stanford, and other universities around the world soon rushed to herald their scientists' involvement.

A telescope in Antarctica, the BICEP/Keck Array, had spotted an obvious twisting signature in our universe's earliest light — the cosmic microwave background (CMB). And these so-called B-mode polarizations were seen as a sure sign for inflation, the event that kick-started the Big Bang.

"This has been like looking for a needle in a haystack, but instead we found a crowbar," one of the co-discoverers, Clem Pryke of the University of Minnesota, said in the team's announcement.

For decades, inflation has remained a widely accepted, but yet-to-be-confirmed theory that takes our universe from subatomic to the size of a grapefruit when the cosmos had existed for just one-trillionth of a trillionth of a trillionth of a second.

Eric Betz *is an associate editor of* Astronomy. *He's on Twitter: @ericbetz.*

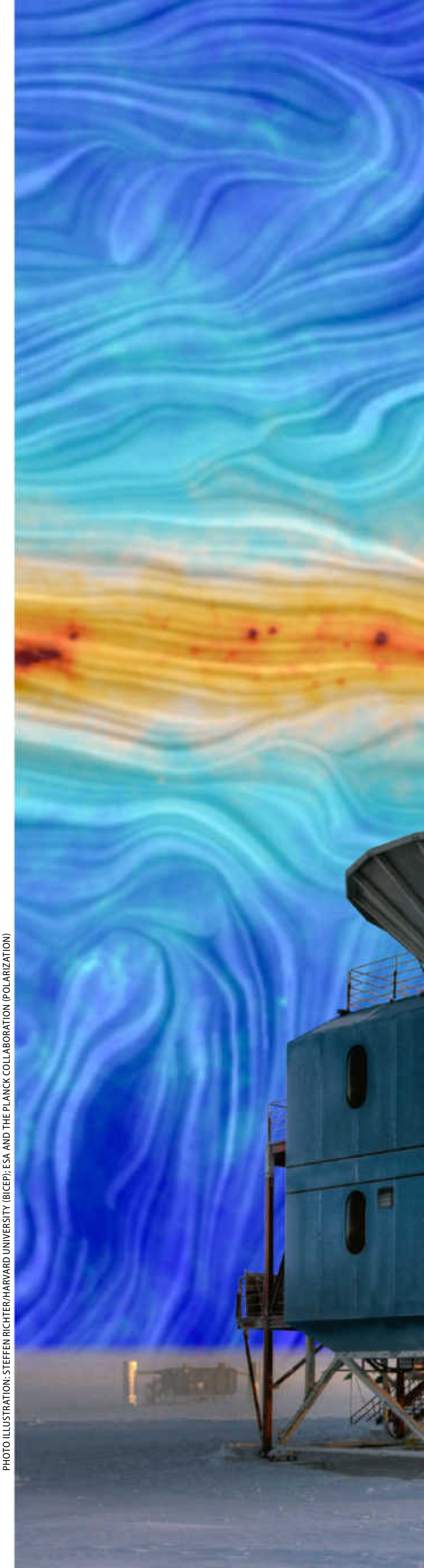
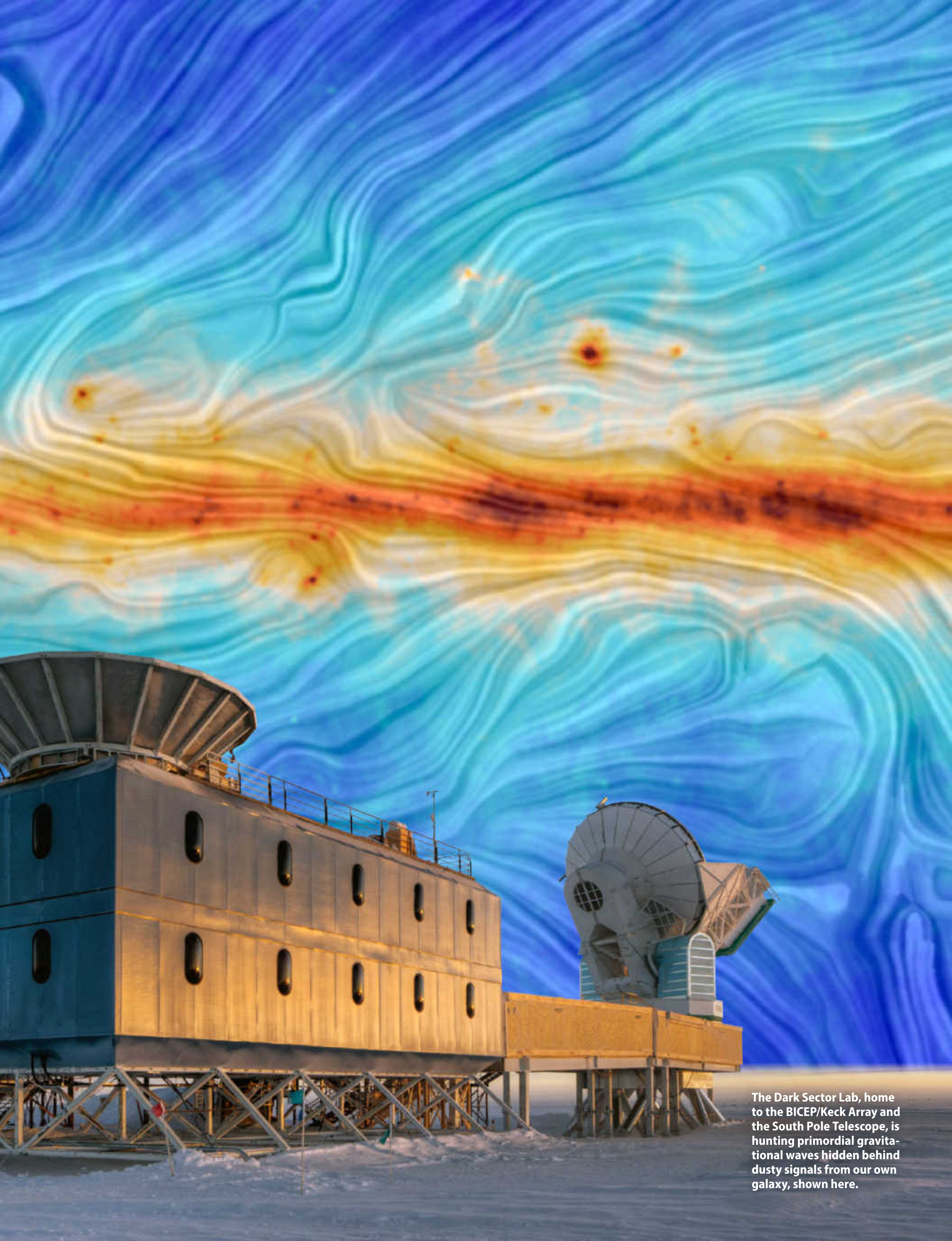


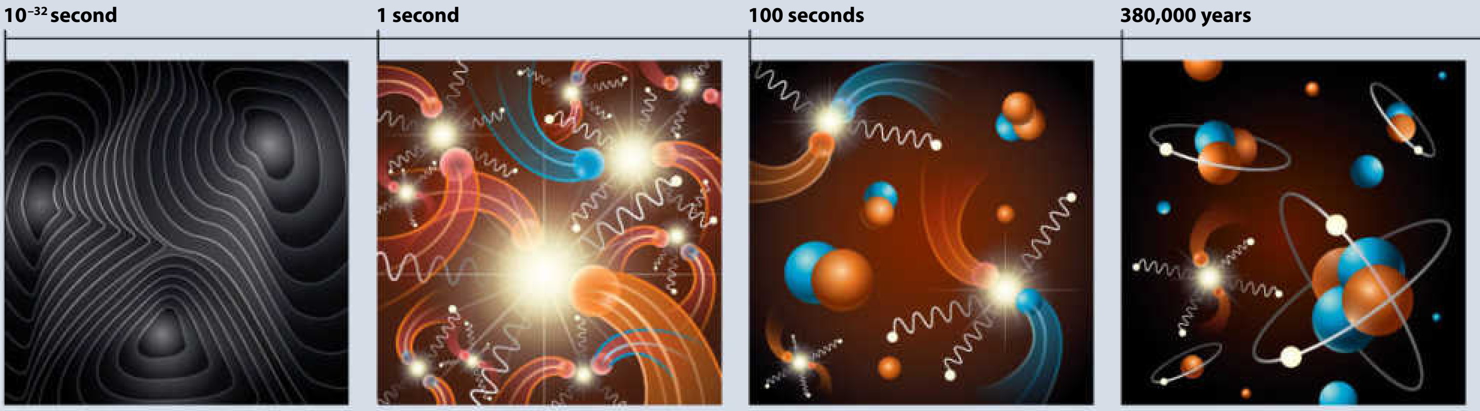
PHOTO ILLUSTRATION: STEFFEN RICHTER/HARVARD UNIVERSITY (BICEP); ESA AND THE PLANCK COLLABORATION (POLARIZATION)



The Dark Sector Lab, home to the BICEP/Keck Array and the South Pole Telescope, is hunting primordial gravitational waves hidden behind dusty signals from our own galaxy, shown here.

After the Big Bang

The history of the universe. *ASTRONOMY*: ROEN KELLY; AFTER ESA



Quantum fluctuations ripple in inflation. Matter and light collide frequently. Cosmic expansion reduces collisions. The CMB forms as photons break free.

Andrei Linde (left) and Alan Guth (right), two of the founding fathers of inflation, toast the discovery of B-modes in 2014. STEFFEN RICHTER

Famed MIT mathematician and cosmologist Max Tegmark, who was in the lecture hall that day, compares the process to an infant in her mother's womb.

"You doubled in size once per day and if you kept doing that for nine months, you would have a very unhappy mommy," he says. "It's the same with the universe."

Inflation theory's miraculous faster-than-light growth spurt puts the bang in Big Bang. (Tegmark likes to think of the Big Bang itself as more of a "cold, little swoosh.") Its violent expansion allowed for the next 13.8 billion years of cosmic evolution, taking us from quarks to atoms, stars, and planets — even life.

And the toasting cosmologists, Guth and Linde, were the first to theorize this period of inflation. In 1979, it emerged from elegant mathematical models as Guth attempted to explain the absence of exotic particles called magnetic monopoles that should have been created in the Big Bang. Our universe isn't missing its monopoles, Guth found. They were simply diluted by inflation's rapid growth.

But inflation provided much more than that. As Guth likes to point out, the Big Bang is not really the theory of a bang at all. It's a description of a bang's aftermath, devoid of the physics of how it exploded, and without clues as to what went bang or why.

He had been working on the problem for half a year when one long night ended with a "spectacular realization," as he labeled it in his journal.

Guth's theory got specific in its description of the bang. It said that space-time had a negative pressure at the beginning — a repulsive force to counter gravity. And that force shoved outward in a fraction of an instant, driving exponential growth that, for a moment, was actually even faster than the speed of light.

Guth's inflation wasn't enough, though. It couldn't make the universe continue to expand the way we see now. His model of inflation turned the cosmos into an endless mix of colliding and converging bubbles. Inflation needed Linde's help. Guth's model encompassed all of the cosmos, but in 1981, Linde calculated the expansion as happening at any one particular point. His version, called chaotic inflation, turned our universe into just one in an infinite multiverse.

In the 35 years since, inflation has taken a central place in explaining other rather curious aspects of our cosmos as well. Better than any other theory, inflation describes why space is flat, and how distant reaches of the universe can appear connected. The theory also can re-create the large-scale structure of the cosmos.

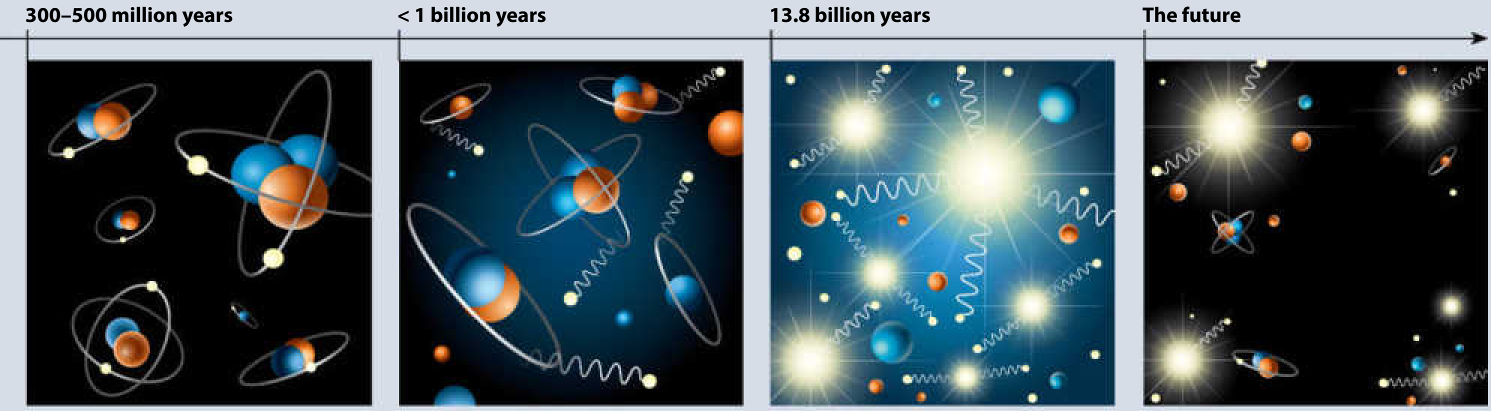
In short, physics is at a loss without inflation. The Standard Model of cosmology loses its beginning.

After the dust settles

But how could such an audacious theory ever be confirmed? Theorists predicted that this exponential growth would leave a discernible mark on the cosmos in the form of enormous gravitational waves that would twist light, creating a polarized signal called a B-mode.

And yet, even as Guth and Linde celebrated the BICEP (pronounced like the muscle) announcement, disbelief about the B-modes discovery was brewing across the community. Some theorists noted the polarization signal was significantly stronger than expected. Others questioned the decision to announce the find at a press conference without first going through peer review.

"Criticism that stood out quickly was the BICEP team's ability to tell the difference between CMB and dust," says astronomer Martin White of the University of California, Berkeley, who's also



All is dark in the cosmos. No stars or galaxies exist yet.

The first starlight breaks up atomic structures, causing reionization.

Light and electrons can now interact. Structures form over billions of years.

Expansion accelerates into the distant future, leading to a "Big Chill."

a scientist for the European Space Agency's Planck spacecraft. The skepticism proved well placed. Planck, which examines a much larger section of sky but at lower resolutions, eventually showed that most of what BICEP detected was interference from foreground dust within our own galaxy. And unfortunately, this relatively nearby signal dirties most of the sky.

It's now been two years since international headlines heralded the discovery of these gravitational waves, and scientists are certain that BICEP saw dust — not inflation. But uncertainty remains about what else was in the signal. Could B-modes from the dawn of time be hidden within?

The race to find the first evidence of inflation is heating up. At least eight instruments are now seeking these whispers from the Big Bang. And to find them, cosmologists first have to decipher everything else in the way.

The Big Bang's still-burning embers

The BICEP team wasn't the first to be frustrated by signals in the cosmic microwave background. In 1964, Bell Labs scientists Arno Penzias and Robert Wilson were using the highly sensitive Horn Antenna in New Jersey to do radio astronomy when they noticed a low-level noise across the sky that wouldn't go away.

The pair eventually ruled out earthly sources, as well as the Sun and even our own galaxy. This signal was coming from everywhere.

What they didn't know was that not far away in Princeton, a group of astrophysicists led by Robert Dicke was preparing to look for the exact signal Penzias and Wilson had discovered.

It had been decades since observations by Vesto Slipher and Edwin Hubble showed our universe was expanding, but the Big Bang debate was still raging. By simply running the cosmos' expansion in reverse, astronomers realized that, at one point, the entire universe would merge.

And Dicke's group theorized, as others had before them, that when the Big Bang set off this expansion, it must have blasted microwave radiation across the universe. Incredibly, their predicted radiation closely matched the mystery signal seen by the Horn Antenna. The two groups went on to publish their finds simultaneously. Penzias and Wilson's serendipitous signal netted them a Nobel Prize in 1978. And the CMB is now a steadfast pillar of Big Bang cosmology.

In the decades since, it's become clear that this CMB radiation fills the cosmos and travels in all directions, where it appears with roughly equal brightness.

The CMB photons are a relic of when the universe became transparent 380,000 years after the Big Bang, as the cosmos cooled to roughly 3,000 kelvins. Before that, the universe was a particle soup too dense for free electrons and protons to combine and form hydrogen, the universe's main building block.

Cosmologists call this the recombination era, and it allowed photons to freely travel through space. So each CMB photon astronomers now see comes from the last place it bounced off an electron nearly 14 billion years ago.

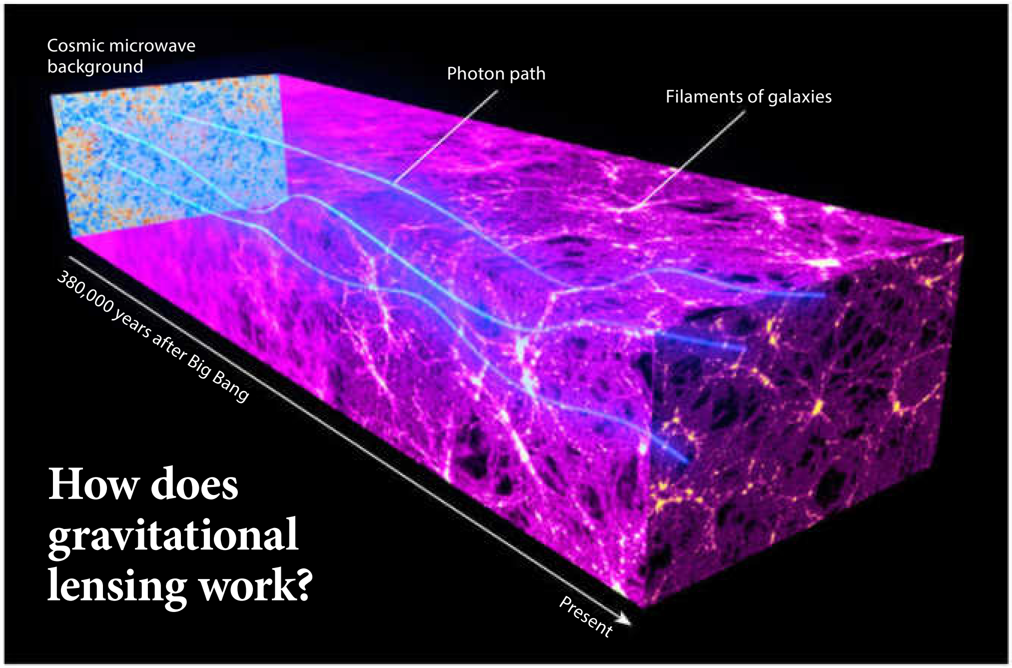
> **CMB photons are a relic of when the universe became transparent 380,000 years after the Big Bang.**

"The maps we make of the CMB brightness show it as it is now arriving here from everywhere else, but if you wait a billion years, there still will be radiation arriving from everywhere else," says Goddard Space Flight Center cosmologist and 2006 Nobel Prize winner John Mather.

This smoothness is also thought to be a product of inflation. At 10^{-34} second after the universe was born, inflation's rapid expansion had already removed any lumpiness from the hot, ionized gas that filled the cosmos.

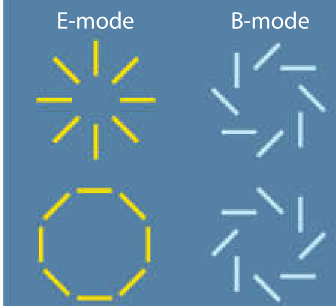
But tiny quantum fluctuations — variations at a level of 1 part in 100,000 — would introduce new regions with differing densities. And gravity drew more and more material to those dense regions. These "seeds" are where galaxies and clusters of galaxies formed, giving the CMB its spots.

Since Penzias and Wilson's find, astronomers have learned that the "anisotropies" — tiny temperature differences in the CMB — are caused by stuff that gets in the way of the signal, like large-scale structures early in cosmic history. CMB photons leaving these structures take slightly longer to reach Earth, giving them a cooler appearance. And the temperature differences allow astronomers to study the cosmos in an entirely new way, revealing our universe's evolution.



Large-scale structures like galaxy clusters deflect cosmic microwave background photons as they travel across the universe toward Earth. This "gravitational lensing" adds tiny distortions that help reveal the cosmos' evolution, but they also make it harder to see signs of inflation. ESA AND THE PLANCK COLLABORATION

E-modes and B-modes explained



Light is an electromagnetic wave — it contains both electricity and magnetism — and polarization occurs in the direction the electric field oscillates. Physicists use line segments to draw these oscillation directions. B-modes are noted by their twists and curls, whereas E-modes are typically curl-free.

ASTRONOMY: ROEN KELLY

Light travels in waves like water moving across the surface of the ocean. Physicists consider such waves polarized if they oscillate in a certain direction. Water waves, for example, push up and down. Our planet's blue sky is polarized as sunlight bounces off particles in Earth's gaseous atmosphere.

Similarly, the CMB is also slightly polarized. But its direction is set by the makeup of matter in the early universe.

Calculating contortions

In 1996, Slovenian theoretical cosmologist Uros Seljak, now a professor at UC Berkeley, was searching for new ways to pull information from the CMB. Seljak suspected this background light still held secrets.

Instead of the large-scale, obvious disturbances from galaxies, Seljak wondered about finding small-scale distortions in the CMB. He theorized that if inflation happened, enormous gravitational waves would have been created during the violent expansion and then rippled across the cosmos. And those waves would also twist the CMB's light, giving it a characteristic curl. If observers could see this field on the sky, it would give physical proof of inflation.

Seljak named these theoretical twists B-modes, after the symbol used for magnetic fields. And he named the electrical polarization component E-modes. His paper and other research led to a surge of instruments designed to search for B-modes.

"The experimentalists did latch onto this idea very quickly," he says. "But of course they did not have the sensitivity to look at this, and it took them almost 20 years to reach that sensitivity."

BICEP is the most ambitious project ever to hunt these B-modes. And it's the first to reach a resolution detailed enough to provide answers. "This has been a race going on since 1997, and now we are finally getting to the level where it's starting to deliver results," Seljak says.

"This has been a race going on since 1997, and now we are finally getting to the level where it's starting to deliver results."

— Uros Seljak, UC Berkeley

Jamie Bock is an experimental cosmologist at the California Institute of Technology in Pasadena. More than a decade ago, he and a handful of other physicists helped design and build BICEP.

And the team has been systematically mapping the skies over the South Pole ever since. Their goal is to measure the level of CMB polarization from B-modes. The team calls this signal the cosmic gravitational-wave background (CGB).

Antarctica's high-altitude, dry climate provides a perfect location for observing the microwave radiation, which is readily absorbed by water vapor elsewhere on Earth.

Relic radiation

BICEP isn't alone in its search for B-modes, but the other competing instruments made compromises to ensure they also could answer broader questions about the universe.

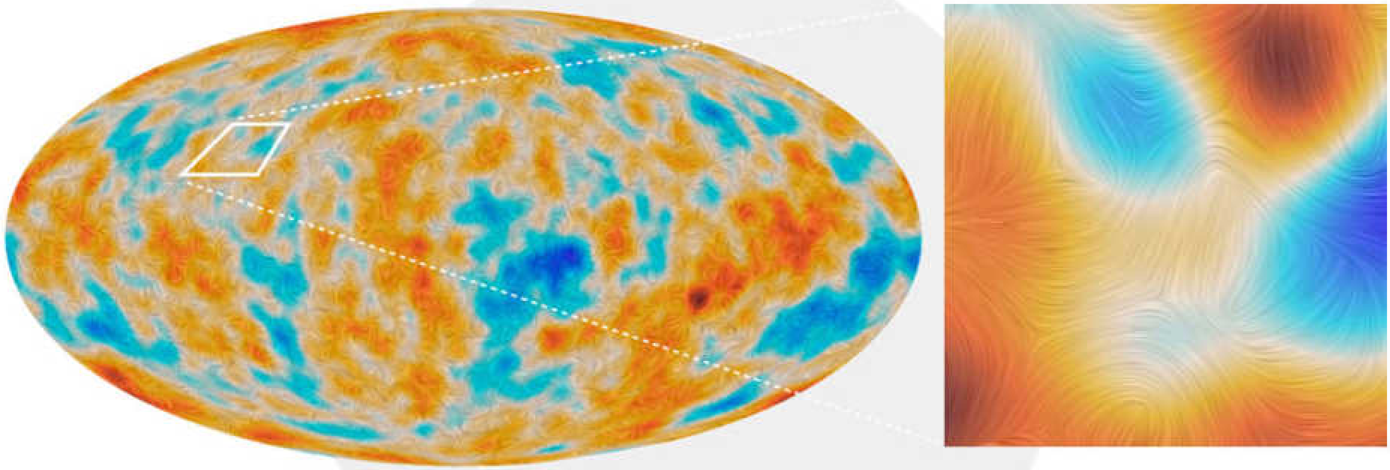
So while BICEP has worked to narrow in on finer measurements, other teams are pushing the limits in the opposite direction. The South Pole Telescope (SPT) and the Atacama Cosmology Telescope, or ACTPol, are using their gargantuan instruments to complete large-scale CMB surveys. Their results will be released soon.

"I think it's healthy for the field to do these different measurements," says Bock.

ACTPol, SPT, and POLARBEAR — another CMB polarization experiment in the Atacama — astronomers are using the CMB to study large-scale structures in the universe, such as early galaxies. When CMB radiation passes through a galaxy cluster, the photons interact with ionized gas, and it changes their wavelengths.

"Every CMB photon is deflected on average 50 times on its way to us," says Suzanne Staggs, principal investigator for Advanced ACTPol.

That allows the CMB to become a backlight, and astronomers can study the spots to create catalogs of new galaxy clusters —



A small fraction of the cosmic microwave background — our universe's first light — was polarized as it interacted with electrons at the dawn of time, causing the light to vibrate in a preferred direction. This twisting pattern can tell astronomers about the distribution of matter in the early cosmos.
ESA AND THE PLANCK COLLABORATION

some of them farther away and larger than any previously known. So, even if they never find B-modes, astronomers already have learned stunning things about the evolution of galaxies in our early universe.

And yet, this signal also complicates detecting twisty B-modes. As polarized CMB light moves through these galaxy clusters, it creates a gravitational-lensing effect that adds an additional twist. And to get at the heart of inflationary B-modes, that signal must be removed just like the signal from dust.

"From what we've seen so far, it looks to me like you'll have to correct for it pretty much anywhere," Staggs says. "But it hasn't been done yet. And then the question is how painful will the correction be and will you be able to do it in a way where you completely believe it."

Another competing mission, which actually includes team members from BICEP, SPT and other efforts, is a balloon-borne telescope called Spider that can fly above much of Earth's interfering atmosphere. It flew over Antarctica in January 2015 collecting CMB data.

A second flight in 2016 will gather observations in frequencies that are also accessible from the ground, allowing for a comparison. That team also is expected to announce its finds soon.

For BICEP, the lensing signal is already at about the level of their instrument noise. But that gives the team an advantage in the race to find inflation — their instruments are the most sensitive. "Right now we're at that breaking point," Bock says.

Fading hints

BICEP's first-generation instrument used an array of just 98 detectors. But by the time observations began in 2015, that number had grown to 2,560 detectors, giving BICEP remarkable light-gathering abilities.

But there's never been any guarantee that B-modes do exist at all. And that's the real risk of BICEP. The instrument represents an all-in bet that primordial B-modes exist in the way predicted by Linde's chaotic inflation theory — the most popular version of inflation.

So even Bock was surprised when BICEP2 saw B-modes blaring so bright across the sky in 2014. Cosmologists measure this signal using a ratio called *r*, which factors gravitational waves against density variations in the early universe. In simple terms, *r* explains inflation's strength. BICEP saw an *r* value of 0.2 — roughly twice what was predicted. This strength was seen as support for Linde's model of chaotic inflation. After the discovery was announced, there was widespread celebration throughout the community.

But some of the first scientific skepticism came from Seljak himself, the guy who gave B-modes their name.

"With everybody else, I was very excited by the results of BICEP, and we were all celebrating," he says. "And then I started looking at these results that were already in conference proceedings from the Planck satellite."

Seljak noticed that the BICEP team was using outdated information to make their comparisons. When the new information from Planck was plugged in instead, it diminished the likelihood that the signal was coming from B-modes outside our galaxy.

"We asked a very simple question: What if BICEP's signal came from dust?" Seljak says. "What came out of this analysis was that the signal could be completely explained by dust.

"It's actually getting less and less convincing," he adds. "The joint analysis between BICEP and Planck showed still just a hint of B-modes, and now even this hint is going away."

The vanish signal has taken support for chaotic inflation with it. But the BICEP team is still searching the sky, turning their gaze to a frequency of 95 gigahertz, a region where their instruments are more sensitive to the CMB than to dust. Once they've added this region to existing measurements, it should reduce their error bars by a factor of two and clarify if any inflation signal remains.

BICEP's latest phase of data will be released this year. Bock says the coming years should show whether the most commonly predicted inflation signals are detectable. They will have eliminated the expected *r* values.

"If there's no signal, it's interesting too," Bock says. That is, if the instruments fail to find anything, theorists will have to go back and explain what might be wrong with our understanding of inflation.

From Seljak's perspective, inflation theory isn't going anywhere anytime soon. Its explanation of the cosmos is too valuable. However, Seljak says the race to find these B-modes from the dawn of time has already ruled out certain versions of the theory — notably, the one that's in most textbooks today. "Inflation is a very convincing theory no matter what," he says. "It has so many things that have been confirmed."

OXYG

The color of life

Most people who view the Orion Nebula (M42) through large amateur telescopes see a greenish hue from glowing oxygen, captured here through a filter that passes that color. Typical M42 images reveal the red emitted by hydrogen. ESO

Eight (protons) is enough

Nature's eighth element allows us to live, breathe, and think, but it also colors the cosmos with its distinctive greenish hue.

by Bob Berman

When we view deep-space objects through backyard telescopes, we typically don't see much color. The big exception is the bright green in certain nebulae. The secret behind this color constitutes a major story. It's a tale that connects with our lives and our minds, and opens portals to a new level of celestial exploration.

Rewind to Mrs. Wombat's sixth-grade science class. There we learned that the universe contains 92 natural elements. All also are found here on Earth. There's no sense pretending they're equally interesting. For example, every breath you take is a gassy mixture of 99.9 percent nitrogen, oxygen, and argon. Argon is inert and just floats there. We don't use it for much of anything besides filling light bulbs. It doesn't help us, and it doesn't hurt us.

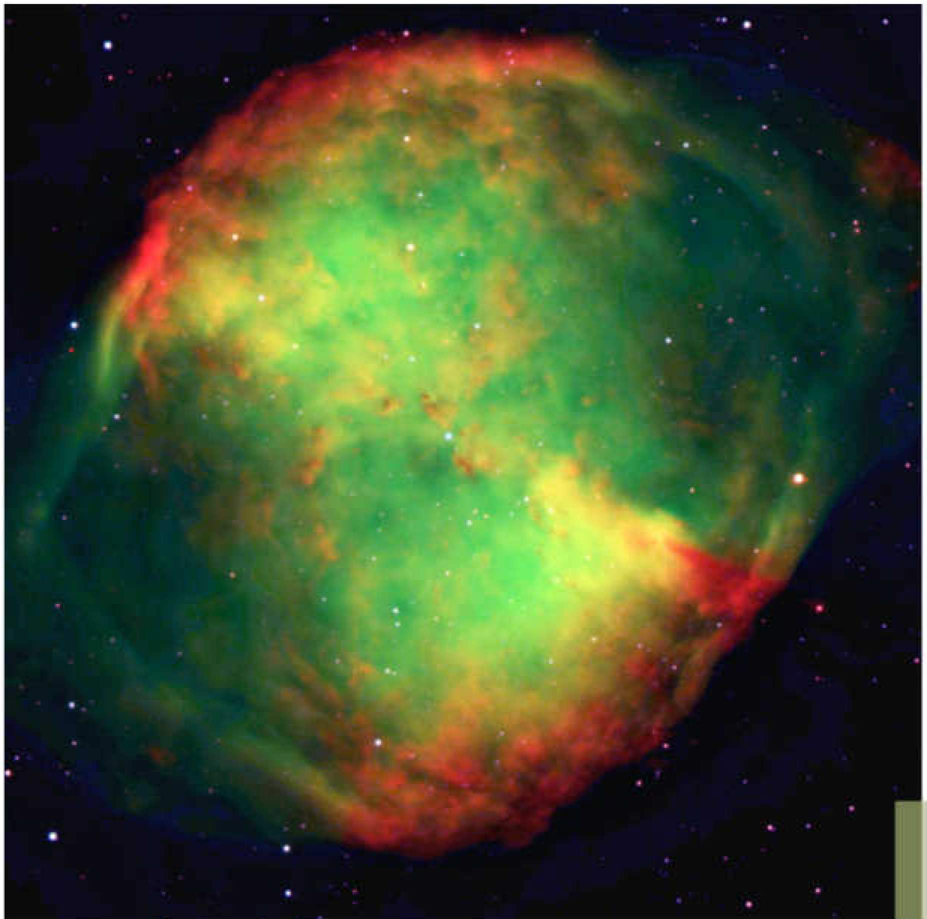
Air also contains a smidgen of water vapor (H_2O), which is two-thirds hydrogen. That's the universe's most common element, Mrs. Wombat insisted, and who were we to doubt her? Hydrogen makes up most of our brains. It's the Sun's primary fuel. It's obviously crucial to our existence.

But now, in terms of cosmic abundance, consider element number two: helium. This takes us back to the not vital category. Our bodies contain exactly zero helium. If all of Earth's helium suddenly vanished, most of us wouldn't notice or care.

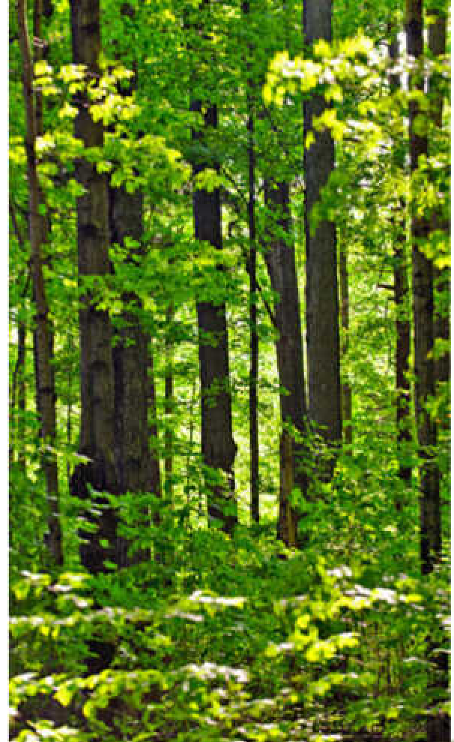
But give helium this: Inside stars, it undergoes fusion to create the universe's third most abundant element, oxygen. Thus we've reached the hero of today's adventure tale. Our lives critically depend on oxygen. It combines so eagerly with other elements that as we look around, either on Earth or through our telescopes, we see it almost everywhere. Although water may be two-thirds hydrogen in terms of its atomic makeup, it's nearly 90 percent oxygen by weight. By the same yardstick, the rings of Saturn are mostly oxygen. So are clouds. And chocolate milk. Kittens.

Because most other elements readily merge with it and soak it up like a sponge, no celestial body has significant *free* oxygen. Earth's atmosphere is the only place in the known universe with lots of it.

Bob Berman *is* Astronomy*'s "Strange Universe" columnist. His newest book is* ZOOM: How Everything Moves *(Little, Brown and Company, 2014).*



This approximately true-color image of the Dumbbell planetary nebula (M27) shows glowing oxygen as green and hydrogen as red. ESO



Plants and trees pump oxygen into the atmosphere, allowing humans to breathe — and the aurora to glow. ELENATHEWISE/ISTOCK/THINKSTOCK

Our blanket of air is 21 percent oxygen for just one reason: plants. They absorb oxygen in one of its combined forms (carbon dioxide), use the carbon to create their stiff, crunchy bodies, and then release molecular oxygen as waste. There are so many plants and trees and kelp, our air is thick with oxygen.

Nobody knew this at the start of the Renaissance. In fact, nobody knew that air is a mix of gases. But the hunt for knowledge was on. Scientists discovered air's two major components almost simultaneously. Scottish physician Daniel Rutherford identified nitrogen in 1772; two years later, British theologian Joseph Priestly isolated oxygen. The elements' main distinction was immediately obvious. One supported life and combustion; the other didn't.

The big nonoxygen player soon acquired a ghoulish reputation. Rutherford called it "noxious air." Mice placed in it quickly died. As for oxygen, it was the precious life-sustaining element everyone was then trying to detect. Because oxygen bonds so easily with most other elements, it makes up two-thirds of animal bodies by weight. And nearly half of the Moon. When wolves howl at the Full Moon, it's basically oxygen calling out to oxygen.

Too much of a good thing

In the beginning, the universe had no oxygen at all. The Big Bang created hydrogen, helium, and a little lithium in case any early stars suffered from depression. But no O. It appeared oh-so gradually starting perhaps 100 million years after the Big Bang — a pathetic seepage, really, trickling in after being forged in the unseen interiors of stars. Some of those early blue suns turned themselves inside out by violently blowing up and scattering their newly minted oxygen through the floorless alleyways of space.

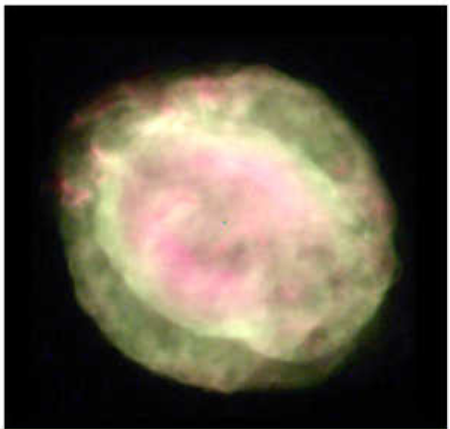
British astrophysicist Arthur Eddington first figured out how the Sun and other stars shine in 1920. He correctly argued that the energy stems from the fusion of four hydrogen atoms into one new helium atom. As stars evolve into old age, they increasingly fuse helium to produce carbon and then oxygen. By the time a star like the Sun reaches the end of its life and collapses into a white dwarf, it's a solid ball of oxygen and carbon and little else.

Before that crushdown unfolds, a typical star with up to about 8 solar masses sheds some material as an expanding gas bubble. This is where we as observers enter the picture. Whenever we look at a planetary nebula, we see an old-age central star surrounded by a glowing doughnut containing countless billions of tons of oxygen. Some of it — along with material from supernova blasts in even more massive stars — eventually helps form new stars and planets.

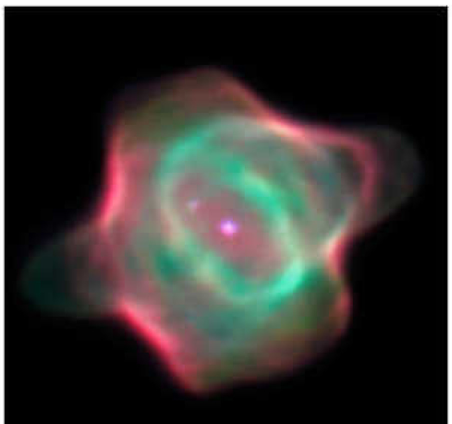
Like ours. Although, interestingly, we didn't have an oxygen atmosphere until just 2.4 billion years ago. Then things started to get out of hand. A mere 300 million years ago, Earth was covered so thickly with plants that our air became superoxygenated. It reached a 35 percent concentration. This let evolution create a nightmare era of hypergiant insects. Some flies back then had wingspans that would rival today's eagles. Try swatting them. Sometimes too much oxygen isn't a good idea.

The green lantern

We're observers, however, so the real trick is how oxygen gets us to pretty colors. (Actually, though it's a colorless gas, oxygen liquefies into an attractive blue fluid.) In its gaseous form, oxygen usually doesn't glow. Not when it's cool. That's because an atom can emit light only when an orbiting electron falls closer to the nucleus.



The Little Gem Nebula (NGC 6818) appears green through amateur scopes thanks to glowing oxygen. R. RUBIN (NASA AMES)/R. DUFOUR AND M. BROWNING (RICE UNIVERSITY)/P. HARRINGTON (UNIVERSITY OF MARYLAND)/NASA



The Stingray Nebula emits green light from doubly ionized oxygen. M. BOBROWSKY (OSC)/NASA

Green often dominates the glow from an aurora. The light arises from atomic oxygen in Earth's thin upper atmosphere, about 60 miles (100 kilometers) above the surface. HINRICH BÄSEMANN

Ordinary tranquil atoms, like those in the gases you're breathing, are not being excited, so their electrons aren't changing orbits and they're not glowing.

Now look into the night sky. Our first experiment works best if you move to Alaska, Canada, Iceland, or northern Europe. That's where you can see the nearest naturally glowing gas — the famous northern lights, or aurora borealis. Though central to our story, the aurora's mysteries drove physicists bonkers during the 19th century and well into the 20th. What exactly is it, and how does it emit its distinctive green color? Spectroscopes, which separate an object's light into its component colors, revealed that most auroral light had a precise wavelength of 557.7 nanometers. But, weirdly, comparing this to various glowing gases in the laboratory didn't yield any answers. Nothing matched.

Physicists were in an uproar. Every explanation proved to be incorrect. Early in the 20th century, German astronomer Julius Scheiner concluded that, "The auroral spectrum is absolutely identical with the cathode spectrum of nitrogen." Beep, wrong! English meteorologist Marshall Watts was equally firm in an antithetical opinion that, "There seems now little doubt that the [glow of] the aurora must be assigned to krypton." Beep! The wrong ideas flowed in torrents. Just a few years later, German spectroscopy expert Heinrich Kayser threw up his hands in exasperation: "We know nothing at all about the chemical origin of the lines of the polar light."

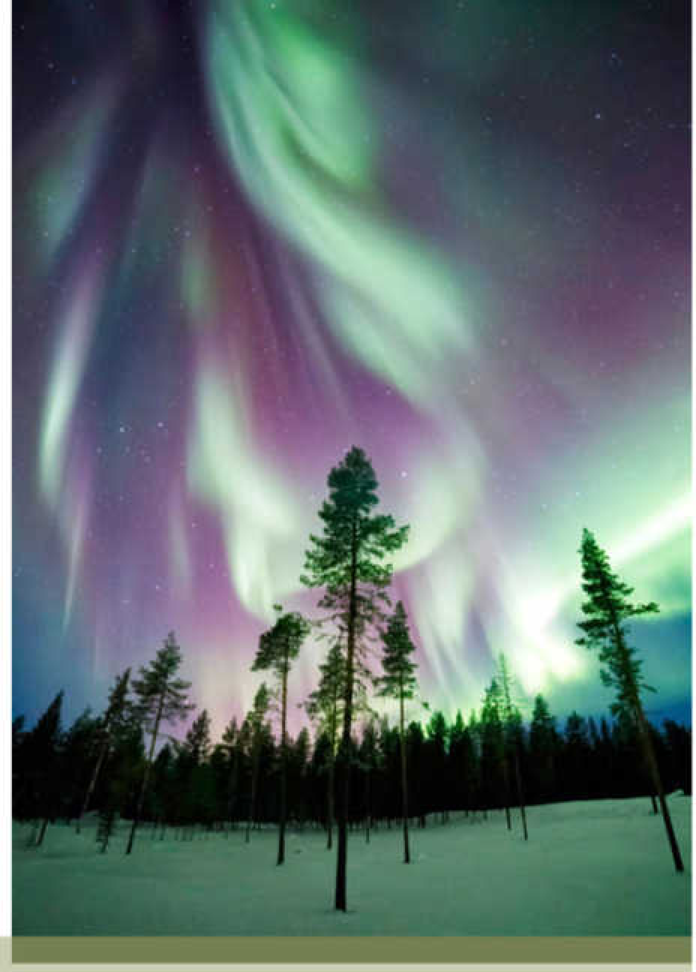
Still, everyone had an opinion. German researcher Alfred Wegener, soon to be famous for his theory of continental drift, published a major work on the atmosphere in which he suggested the auroral glow came from a new "geocoronium" gas. This notion of an undiscovered element producing a green light was not new. For nearly a century, scientists widely attributed the odd green glow of nebulae — which shine at an emerald wavelength of 500.7nm — to a substance called "nebulium." The cosmos seemed awash with elements not found on Earth.

Decades passed. Lars Vegard, a Norwegian expert in the physics of the aurora, was sure he'd solved the green puzzle in 1924. As he wrote in *Nature*, "The typical auroral spectrum is emitted from solid [dust particles of] nitrogen."

They were all wrong. As it turned out, the element nebulium does not exist, and neither does geocoronium. All along, the source of the green light was ordinary oxygen.

In both places — deep space and high in our atmosphere — the mystery arose from the near-vacuum conditions. You see, as Mrs. Wombat used to point out, oxygen's electrons have certain allowable orbits around the nucleus. But when excited by solar electrons or a star's high-energy ultraviolet radiation, the electrons jump to energetic yet unstable positions where they can't stay. Near Earth's surface where the air is thick, these excited atoms hit others so quickly that they dissipate their extra energy before they can emit it as light.

But in the rarefied upper atmosphere and also in the hard vacuum of deep space, oxygen's electrons can linger in a "metastable" state before falling to a lower orbit and emitting photons. They thus give off colors never produced under more earthly conditions. This "forbidden radiation," as it started to be called, comes in a precise shade of yellow-green at 557.7nm in the northern lights and blue-green at 500.7nm for planetary nebulae. (The latter emission originates from doubly ionized oxygen, which has



Although the green glow of oxygen dominates this aurora, it also displays purple hues from nitrogen molecules. JUSTINREZNICK/ISTOCK/THINKSTOCK

lost two of its normal complement of electrons.) Oxygen. Nothing exotic, after all that trouble. Mystery solved at last.

Oh say, can you see it?

Happily, these oxygen emissions happen just where the human eye is most sensitive. Still, in 2014 during my annual aurora tour to Alaska, which I've been conducting for decades, some of the 44 guests said they saw no color. To them, the aurora appeared pale white. I was startled because to my own eyes, the green was so intense that it seemed like a traffic light. So I took a vote. Result: Half the group saw the color as a rich green; one-quarter perceived it as pale green; and one-quarter saw no color at all. It thus became apparent once again that human eyes vary in their ability to see color at low light levels.

This individuality carries over to telescopic observations. Most people viewing the Orion Nebula (M42) through large backyard instruments — 10 inches in aperture and above — perceive a distinct green color. But not everyone does. Probably the most reliable nebulae that display rich green color are compact planetaries such as the Cat's Eye Nebula (NGC 6543) in Draco and the Little Gem Nebula (NGC 6818) in Sagittarius. I used to lament that since most amateurs do not possess spectroscopes, they can't fully examine and enjoy these hues. Recently, however, I've realized that when a celestial body emits most of its light in one narrow part of the spectrum — as planetaries do with their glowing oxygen at 500.7nm — you really don't need a spectroscope. Your eye perceives accurate color through the eyepiece.

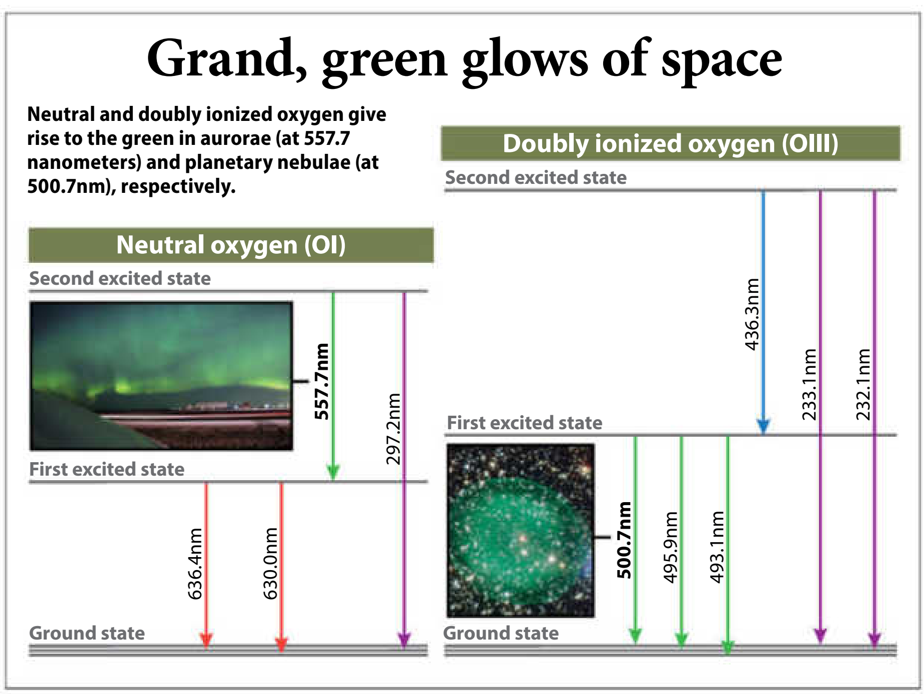
A spectroscope is most useful when observing mixtures of colors. Using one to look at Betelgeuse or Sirius is a wondrous experience because not only are all the emissions laid out side by side in dramatic fashion, but the differences between stellar spectral types also become beautifully striking. Betelgeuse shows numerous absorption lines, even some from molecules, whereas Sirius displays a simple series of sharp hydrogen lines overlaid on a vivid explosion of green, blue, and red. In contrast, a planetary nebula is a one-note composition with virtually all its light coming from that single green oxygen line.

With the Orion Nebula, glowing oxygen dominates the visual eyepiece view by imparting an obvious jade color. Through a spectroscope, however, other emissions show up because glowing hydrogen and scattered starlight also fill the stew pot. To make the shift complete, take a photo. Now a surprising thing happens — the green vanishes. It's gone because it is "burned out" and overexposed as white. Suddenly, the crimson light of hydrogen at 656.3nm rules. This color doesn't register through a visual eyepiece because at faint levels, human vision is completely blind to deep red.

Bottom line: What colors you see — and the issue of whether oxygen's green glow dominates the scene — depends on your technique. Visually, oxygen rules. Photographically, it does not except in planetary nebulae. And spectroscopically, it's a toss-up except again with planetaries. Through it all, and no matter what equipment you use, observing glowing oxygen is educational and fun.

The three wise isotopes

Oxygen also provides keys to critical celestial puzzles. That's because it comes in three flavors. Oxygen has three stable isotopes, each of which has the same number of protons but a different number of neutrons in its nucleus. All have identical chemical properties, and you could happily breathe any of them. Every



ASTRONOMY: ROEN KELLY; BILL MARSH (AURORA); ESO (GREEN BUBBLE NEBULA)

An intriguing spiral pattern developed in this aurora over the Lofotr Viking Museum on the Norwegian island of Vestvågøya. ALLEN HWANG

The stars of Orion shine through the bright rays of this oxygen-rich greenish aurora. STEPHANE VERMETTE

Folded auroral bands, like these seen from Fairbanks, Alaska, occur during so-called substorms, when solar activity injects energetic electrons into Earth's atmosphere and causes oxygen atoms to emit their characteristic greenish glow. MARVIN NAUMAN

oxygen atom contains eight protons. The vast majority of these also have eight neutrons. Add up the protons and neutrons in this lightest-weight oxygen atom and you get 16, so this most common form is called O-16. But a small percentage of oxygen has one or two extra neutrons — O-17 and O-18, respectively.

The first stars in the universe created almost 100 percent pure O-16. Later generations made progressively larger proportions of the heavier isotopes. Nowadays, at least here in the solar system, about 1 in 500 oxygen atoms contains an extra neutron while about 1 in 2,000 have two extra. Still with us?

The ratios of O-16, O-17, and O-18 isotopes in every potato chip, puppy, and rock here on Earth follow a simple relationship. But if you send a lander to Mars and sample its material, as NASA has now done several times, you'd find that martian rocks with the same ratio of O-18 to O-16 as earthly specimens will have a slightly higher ratio of O-17 to O-16. The difference in the isotope ratio between our two planets is 300 parts per million, with Mars consistently higher.

So oxygen isotopes are like fingerprints. They tell you which world a rock came from. That's how we can be sure a particular meteorite originated on the Red Planet. We also have meteorites from the large asteroid Vesta, whose ratio of O-17 to O-16 is about 300 parts per million lower than Earth's.

Here's where things get weird. The oxygen in Moon rocks has the same isotopic ratio as terrestrial objects. It's as if the Moon is Earth! Any difference is less than 1 part in 50,000.

This presents a problem, however. Nearly every planetary scientist thinks the Moon resulted from a long-ago collision between Earth and a Mars-sized body dubbed Theia. The laws of physics show that for the impact hypothesis to work, much of the Moon should be Theia material and thus should have a distinct and alien oxygen-isotope ratio. Yet the Moon appears made of earthly stuff.

Every few years, some researchers will publish a journal article that either tries to explain this oxygen problem or else uses it to discredit the collision hypothesis. A major 2014 reanalysis of Apollo moon rocks claimed to find a minuscule disparity between our worlds' oxygens — just barely enough, perhaps, to keep alive the idea of the Moon's violent birth.

So take a deep breath. Ponder the element that energizes your brain so you *can* contemplate the cosmos. And someday, if we spot oxygen's distinctive auroral glow on an exoplanet, the traffic-light green can serve as a "go" signal.

For, almost surely, we will have found the signature of plants on another world. It will be our beloved oxygen, once again guiding our discoveries.

THAT'S NO MOON …

Q: COULDN'T HYPERION'S LOW DENSITY AND SPONGY TEXTURE BE BETTER EXPLAINED BY IT BEING A CAPTURED COMET?

***Jose Gonzalez,** Bethlehem, Pennsylvania*

A: Saturn's moon Hyperion presents a puzzle to planetary scientists with its spongelike surface, which looks more like a sea creature than a rocky satellite. It's also oddly large for such an irregularly shaped moon, with an average diameter of about 170 miles (275 kilometers).

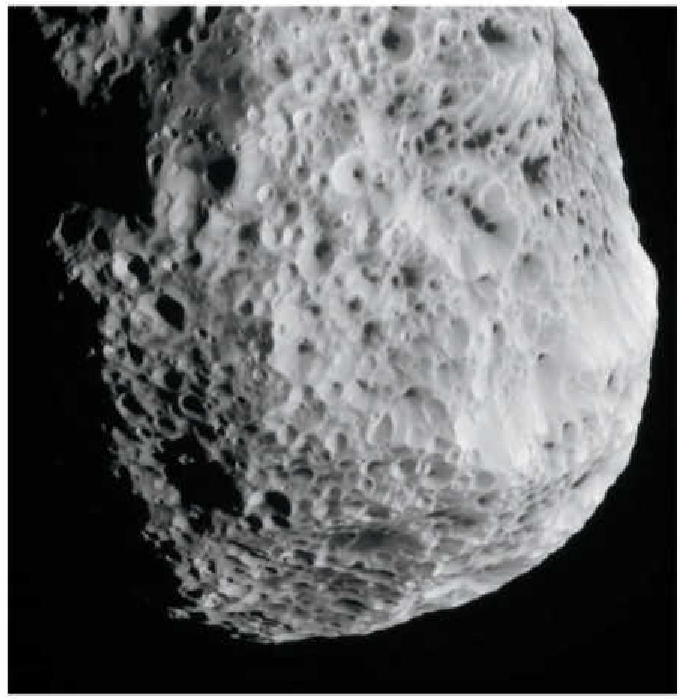
NASA's Cassini Saturn orbiter was the first to see Hyperion in sufficient detail to make out its strange craters. And over the past decade, Cassini also has helped make the origins of this alien object much less mysterious.

The moon's minuscule gravitational pull on Cassini shows Hyperion is made mostly of empty space. And like the rest of Saturn's moons, ice is its primary building block with little rock, so its density is quite low. That helps explain the satellite's craters. Most impact craters we're familiar with form after an object smacks into a body's surface and sends out an explosive shock wave that blasts material in a circular pattern. But on Hyperion, astronomers suspect impactors actually compress the weak surface, and the ejected material is blown off the moon entirely. And because the satellite is so porous, the craters remain pristine.

That faint gravity also helps explain Hyperion's chaotic rotation, which resembles the bizarre movement New Horizons saw with some of Pluto's moons.

But could it be a comet? At this point, that seems unlikely. The moon is several times larger than any comet seen before. However, astronomers do see it as cometlike. The dust-covered moon has a similar makeup as comets and has been repeatedly bombarded by debris over the years. It also never had to cope with the Sun's harsh rays in the inner solar system. Astronomers suspect Hyperion formed in an icy impact, which left the moon as a thin rubble pile without the needed density to completely compact.

Eric Betz
Associate Editor



NASA's Cassini Saturn orbiter snapped this image of Hyperion during its final close-up with the odd moon on May 31, 2015. Astronomers have long been puzzled by the satellite's spongelike appearance. NASA/JPL-CALTECH/SSI

Q: VEGA IS SAID TO ROTATE AT ABOUT 87 PERCENT OF THE SPEED THAT WOULD TEAR IT APART. IF IT EVER REACHED THAT SPEED, WHAT WOULD AN OBSERVER ON EARTH WITNESS?

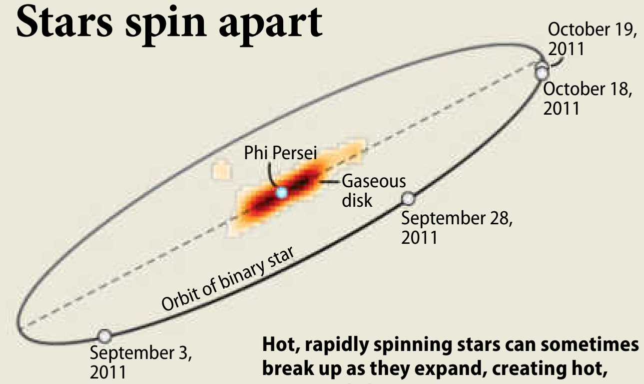
Ralph Heide
El Segundo, California

A: A hot star, such as Vega, will gradually increase its luminosity and also grow in size as it ages. As the star expands, it should actually spin slower to conserve angular momentum — just like an ice skater stretching out her arms. At the same time, the core is becoming more dense and compact as hydrogen is "burned" to helium ash, and thus the inner layers of the star should spin faster. Interestingly, observations show that the core and outer layers of the stars mostly synchronize their spin through viscosity so the speed of the star's surface remains roughly constant during this time.

That is not the end of the story. The outer layers of the star feel less gravitational pull as they expand, making it easier for material to escape. If the star keeps expanding while maintaining constant surface speeds, eventually the material at the equator will fly off. We think some stars might be born spinning so fast that they do reach "breakup" during their hydrogen-burning lifetime.

Possible evidence for this picture comes in the form of hot, gaseous disks seen around some hot stars — the so-called "Be" stars, where B refers to the temperature spectral type and little "e" means that the star

Stars spin apart



Hot, rapidly spinning stars can sometimes break up as they expand, creating hot, gaseous disks. *ASTRONOMY*: ROEN KELLY; AFTER MOURARD ET AL. 2015 (*ASTRONOMY & ASTROPHYSICS*)

shows emission lines. We think gas at the equator of a fast rotating star gets nudged out of the photosphere and into orbit, pushing on material that left earlier until a little disk forms. The accompanying photo illustration is a real infrared image of such a gaseous disk we recently captured using the CHARA Interferometer on Mount Wilson. Occasionally amateur astronomers discover normal B stars that all of sudden become Be stars. But how can the gas disk appear so suddenly, within a few weeks? We someday hope to take a picture of this happening in real time with CHARA to find out.

John Monnier
University of Michigan

During the August 21, 2017, total solar eclipse, the Moon's inner shadow will move across the United States from Oregon to South Carolina as our satellite passes in front of the Sun in Earth's sky. *ASTRONOMY:* ROEN KELLY

Q: PLEASE EXPLAIN WHY THE TOTAL SOLAR ECLIPSE IN AUGUST 2017 STARTS ON THE WEST COAST AND PROGRESSES EASTWARD.

Jeff Panther
Tucson, Arizona

A: At first glance, this seems counterintuitive. After all, doesn't everything in the sky rise in the east and set in the west? Yes, but that's an apparent motion caused by Earth's real motion of spinning once a day on its axis. Because our planet rotates from west to east, everything in the sky seems to be going in the other direction.

When we examine the true motions of the celestial objects we can track over short timespans — the Sun, the Moon, planets, and asteroids (comets are special cases that can have all kinds of trajectories because they originate so far away) — we find they move from west to east unless Earth is passing them in space, when they appear to move backward (retrograde, or east to west).

Let's concentrate our discussion on the two objects crucial to the 2017 eclipse, the Sun and the Moon. If you watch the Sun throughout the year, or the Moon through one of its orbits around Earth, you'll discover that each moves eastward through the stars, specifically the constellations of the zodiac.

So, one month the Sun appears in front of the stars of Leo the Lion. The next month, it's in the constellation to Leo's east, Virgo the Maiden.

The Moon is swifter, making more than 12 orbits of Earth in a year. So, if the Moon and Sun are near one another — and they're on top of each other during an eclipse — it will be the faster Moon catching up to and passing the Sun. Because both are moving from west to east, the resulting shadow of the Moon will start on the western side of Earth and move eastward.

Michael E. Bakich
Senior Editor

Q: IF WE KNOW THE PATH THAT BOTH THE MILKY WAY AND OUR SOLAR SYSTEM HAVE BEEN ON, COULD HUBBLE NOT LOOK BACK ON THAT PATH AND SEE BOTH AT SOME POINT IN THE PAST?

Jim Brady
Winchester, Massachusetts

A: We say that a telescope looks back in time when it looks into space, but that is not exactly true. Light takes some amount of time to travel from one object to another; it is not instantaneous. Light covers 186,282 miles (299,792 kilometers) each second.

And because there are 92,957,130 miles (149,599,999km) between Earth and the Sun, the light that I see at this moment actually left the Sun 500 seconds, or 8.3 minutes, ago. The solar system is only a couple of light-years wide, and so we cannot — now, today — see what any part of it looked like more than about a year ago.

The same principle is true when the Hubble Space Telescope, like any telescope, looks toward a cluster of stars in one of the Milky Way Galaxy's spiral arms.

Take the Pleiades (M45) for example. If Hubble were to observe this cluster tonight, the light that it collects left the Pleiades more than 400 years ago. But we can't pick an arbitrary point in that cluster's history to look at; we are at the whim of light and how far away from us M45 is. Light from earlier in the cluster's life has already passed us, and light from later in its life has yet to reach us.

Hubble only sees an object at some small time frame in that object's past — and it depends entirely on how far away from us that object is.

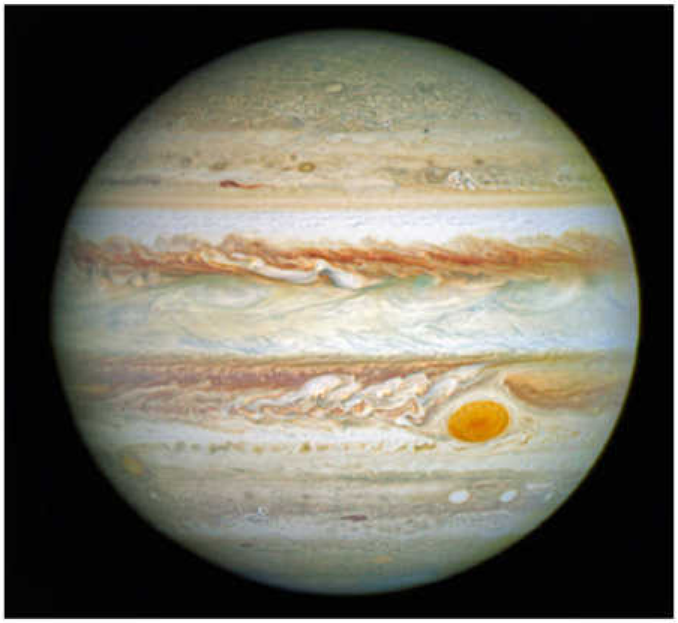
No telescope can look at many different times separated by millions of years in a celestial object's evolution.

Liz Kruesi
Contributing Editor

Send us your questions

Send your astronomy questions via email to **askastro@astronomy.com**, or write to Ask Astro, P. O. Box 1612, Waukesha, WI 53187. Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

March 2016: Jupiter dazzles all night



Intricate detail of Jupiter's dynamic atmosphere shows through telescopes of all sizes, especially in the weeks around its early March opposition. NASA/ESA/A. SIMON (GSFC)

March brings the onset of spring and the return of warmer weather to much of North America. The balmy conditions should prove enticing for observers eager to sample the planetary treasures that were largely lacking during winter's cold nights. The stars of the show are Jupiter and Mars. The former hits its peak in March and remains visible all night while the latter dominates the morning sky as it enters prime viewing season. And don't overlook stunning Saturn, which shares the predawn stage with Mars.

Let's begin our monthly tour in the western sky as darkness falls. You'll need binoculars if you want to spot **Uranus**. On March 1, the ice giant world stands nearly 20° above the horizon as the last hints of twilight fade away.

Uranus shines at magnitude 5.9 among the background stars of Pisces. To find it, first locate 2nd-magnitude Alpha (α) Andromedae, the star marking the top corner of the Great Square of Pegasus. Then scan 25° to the left and pick up 4th-magnitude Epsilon (ε) Piscium. The planet lies 2° to Epsilon's left. The nicest view occurs March 10, when Uranus appears 2° due north of a slender crescent Moon.

The planet sinks lower with each passing day and disappears into the Sun's glare after midmonth. That's too bad because it means observers won't be able to see it when it passes less than 1° south of **Mercury** on the 31st. The innermost planet then shines at magnitude –1.6, however, and may show up through binoculars if you have an excellent sky. Mercury will have its finest evening appearance of 2016 in April.

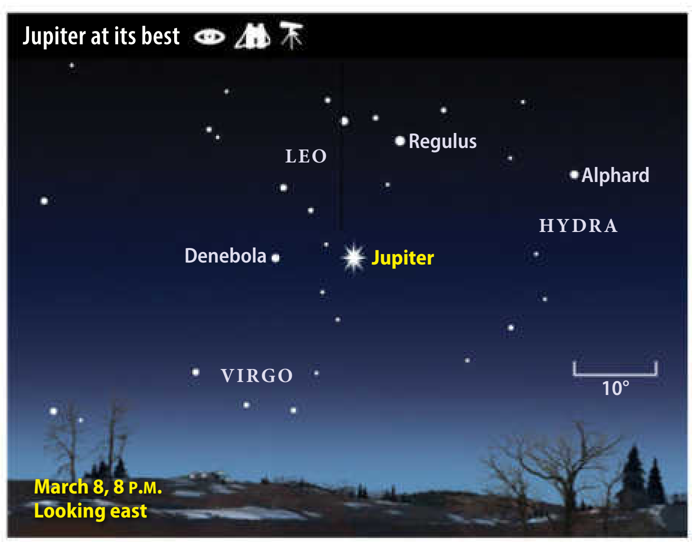
The western evening sky's meager offerings mean that most observers will focus their attention to the east. **Jupiter** reaches opposition and peak visibility March 8. Because the planet lies opposite the Sun in our sky, it rises at sunset and sets at dawn. The planet also shines brightest at opposition. At magnitude –2.5, it appears 2.5 times more luminous than the night sky's brightest star, Sirius. Jupiter spends March in southern Leo, and within 1° of 4th-magnitude Sigma (σ) Leonis during the month's first 10 days.

Opposition also means that Jupiter lies closest to Earth and thus appears largest when viewed through a telescope. The planet's disk spans 44", big enough that any scope will reveal atmospheric details. Look for two prominent dark bands straddling a brighter equatorial zone. A small telescope typically shows these belts with sharply defined edges. Larger instruments reveal turbulence.

Although Jupiter's atmosphere can keep an observer busy for hours, don't overlook the four bright moons that endlessly circle the planet. An individual moon spends most of its time either east or west of Jupiter, but once each orbit it passes in front of the planet in what astronomers call a transit. During a transit, the moon also casts its shadow onto the jovian cloud tops, where it appears as a small-yet-distinct black dot.

A moon and its shadow nearly overlap at opposition because the light source (the Sun) lies directly behind our vantage point. Observers in the eastern half of North America can see this happen twice the evening of March 7. Europa and its shadow transit

Martin Ratcliffe provides planetarium development for Sky-Skan, Inc., from his home in Wichita, Kansas. Meteorologist **Alister Ling** *works for Environment Canada in Edmonton, Alberta.*



The solar system's largest planet resides among the background stars of Leo the Lion at its March 8 peak. ALL ILLUSTRATIONS: *ASTRONOMY*: ROEN KELLY

RISING**MOON**

Striking craters stand side by side

The northeastern quadrant of a waxing crescent Moon features a prominent pair of large craters. Named for mythological musclemen, Atlas and Hercules have appropriately striking features.

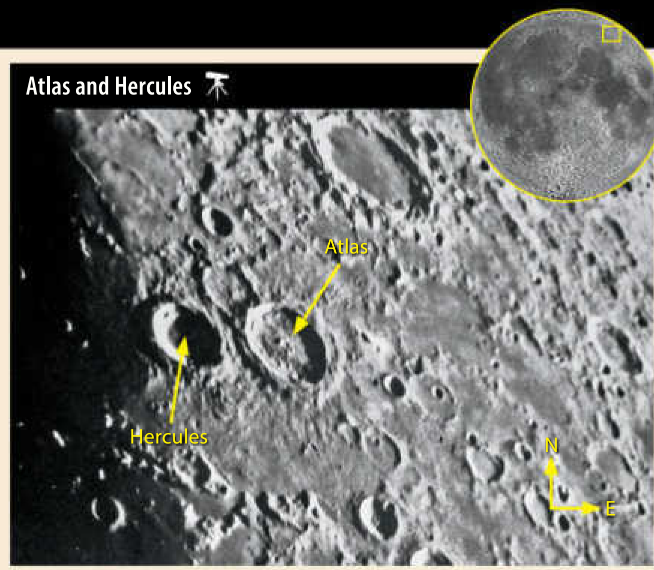
Their chiseled forms seem to pop out the evening of March 12 as the Sun rises in the lunar sky. Atlas, the one closer to the limb, sports a rough floor and a central peak. Hercules lies immediately to its west, straddling the dividing line between night and day known as the terminator. On the 12th, the inner walls of Hercules' western rim face the brilliant Sun while their eastern counterparts remain in deep shadow. Return to this crater on the 13th, and its floor will be on full display. Surprise: It is a pool of frozen lava with the barest hint of a central peak and a sharp-rimmed crater just south of center.

An apron of debris surrounds Atlas and Hercules. Can you tell which one drapes over the other? It may help to look again under reversed lighting conditions, when the setting Sun illuminates the craters' eastern flanks March 26. Don't despair if you can't figure it out — even scientists disagree as to which crater formed first.

Luna slowly turns its nose up at us beginning on the 18th. Key in on the limb northeast of Hercules and watch as the dark floor of Mare Humboldtianum shifts farther out of sight from night to night. The tilt of the Moon's axis isn't really changing. Rather, its equator doesn't coincide with its orbit around Earth, so we see it from slightly different perspectives. Astronomers call this apparent nodding motion libration.

Anytime after First Quarter phase (March 15) is close to high noon for Atlas and Hercules. Without the highlighting effect of shadows, Atlas practically disappears. In contrast, Hercules' lava lake stands out next to its light-hued neighbor.

Atlas and Hercules



Craters named for mythological strongmen stand out on the terminator of a waxing crescent Moon. *CONSOLIDATED LUNAR ATLAS*/UA/LPL; INSET: NASA/GSFC/ASU

Jupiter's disk for nearly three hours starting around 6:10 P.M. EST. Innermost Io and its shadow follow shortly thereafter, crossing the cloud tops from 7:28 to 9:43 P.M.

These two repeat their transits in magnificent fashion the night of March 14/15 but with an added twist: You'll see Io overtake Europa as the transit nears its end. Europa begins to transit at 9:27 P.M. EDT, and its shadow arrives on the disk 19 minutes later. Io's transit starts at 10:12 P.M. with its shadow following nine minutes after.

Now the race is on. During the next two hours, Io catches up to its neighbor. At around 11:15 P.M., the two dark shadows appear about halfway across the planet with Io itself midway between them and Europa farthest west. Io passes Europa's shadow shortly before midnight when the inner

— Continued on page 42

METEORWATCH

Dusty debris sets the evening aglow

March finds us in the meteor calendar's longest gap. Just a few minor showers and occasional sporadics sprinkle the sky. But you still can see the dust from countless comets and pulverized asteroids. This material fills the inner solar system in a disk that coincides with the planets' orbital plane, or ecliptic. Sunlight illuminates the dust, creating a faint glow visible under clear dark skies after twilight ends. This so-called zodiacal light shows up best now because the ecliptic makes a steep angle to the western horizon after sunset.

Look to the west after darkness falls during March's first 10 days, when the Moon is out of the sky. The cone-shaped zodiacal light appears a little dimmer than the Milky Way and reaches from the horizon up toward the Pleiades star cluster.

Zodiacal light

The first 10 days of March provide observers with a great chance to see the glow of solar system dust after evening twilight fades. STEPHEN G. CULLEN

OBSERVING HIGHLIGHT On March 8/9, observers along a narrow track that cuts across Indonesia and the Pacific Ocean will see a total solar eclipse.

STAR DOME

How to use this map: This map portrays the sky as seen near 35° north latitude. Located inside the border are the cardinal directions and their intermediate points. To find stars, hold the map overhead and orient it so one of the labels matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

The all-sky map shows how the sky looks at:

10 P.M. March 1
10 P.M. March 15
9 P.M. March 31

Planets are shown at midmonth

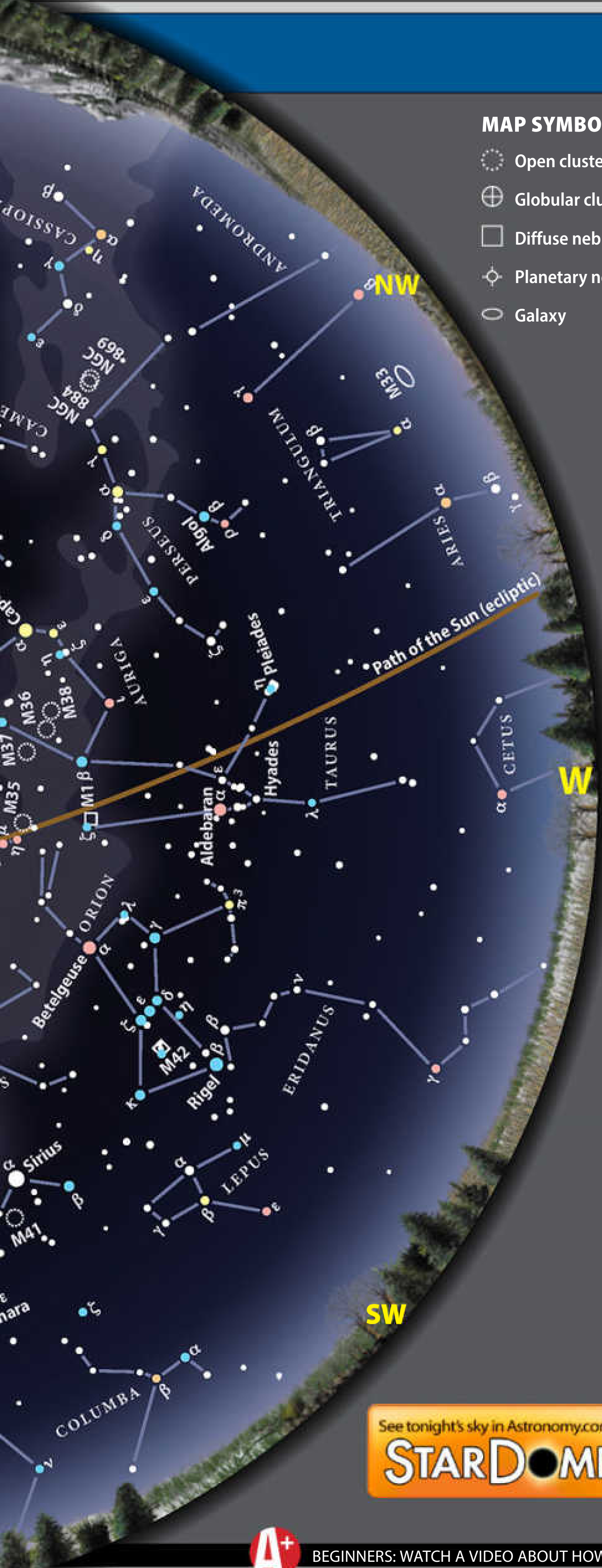
STAR MAGNITUDES

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

STAR COLORS

A star's color depends on its surface temperature.

- The hottest stars shine blue
- Slightly cooler stars appear white
- Intermediate stars (like the Sun) glow yellow
- Lower-temperature stars appear orange
- The coolest stars glow red
- Fainter stars can't excite our eyes' color receptors, so they appear white unless you use optical aid to gather more light



MAP SYMBOLS

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

MARCH 2016

Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

Calendar of events

1 Last Quarter Moon occurs at 6:11 P.M. EST

2 The Moon passes 4° north of Saturn, 2 A.M. EST

3 Asteroid Ceres is in conjunction with the Sun, 5 P.M. EST

6 Asteroid Juno is stationary, 11 A.M. EST

7 The Moon passes 4° north of Venus, 6 A.M. EST

SPECIAL OBSERVING DATE

8 Jupiter reaches its 2016 peak today, shining at magnitude –2.5 and appearing 44.4" across through a telescope.

8 Jupiter is at opposition, 6 A.M. EST

New Moon occurs at 8:54 P.M. EST; total solar eclipse

10 The Moon is at perigee (223,389 miles from Earth), 2:04 A.M. EST

The Moon passes 1.9° south of Uranus, 8 P.M. EST

14 The Moon passes 0.3° north of Aldebaran, 10 A.M. EDT

15 First Quarter Moon occurs at 1:03 P.M. EDT

Asteroid Hygiea is at opposition, 8 P.M. EDT

20 Vernal equinox occurs at 12:30 A.M. EDT

Venus passes 0.5° south of Neptune, 10 A.M. EDT

21 The Moon passes 2° south of Jupiter, midnight EDT

23 Full Moon occurs at 8:01 A.M. EDT; penumbral lunar eclipse

Mercury is in superior conjunction, 4 P.M. EDT

25 Saturn is stationary, 9 A.M. EDT

The Moon is at apogee (252,355 miles from Earth), 10:17 A.M. EDT

28 The Moon passes 4° north of Mars, 3 P.M. EDT

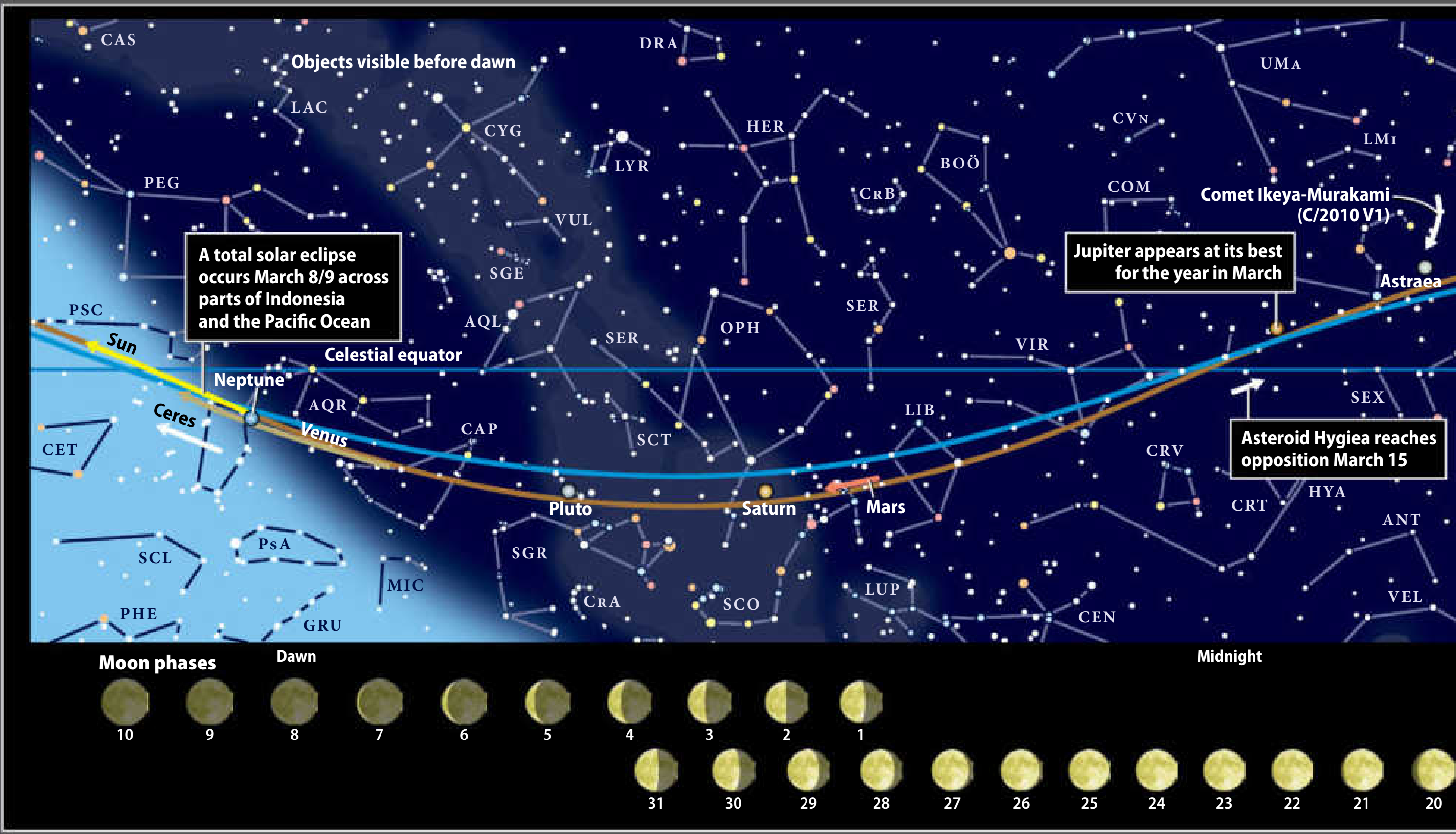
29 The Moon passes 3° north of Saturn, 11 A.M. EDT

31 Last Quarter Moon occurs at 11:17 A.M. EDT

BEGINNERS: WATCH A VIDEO ABOUT HOW TO READ A STAR CHART AT **www.Astronomy.com/starchart.**

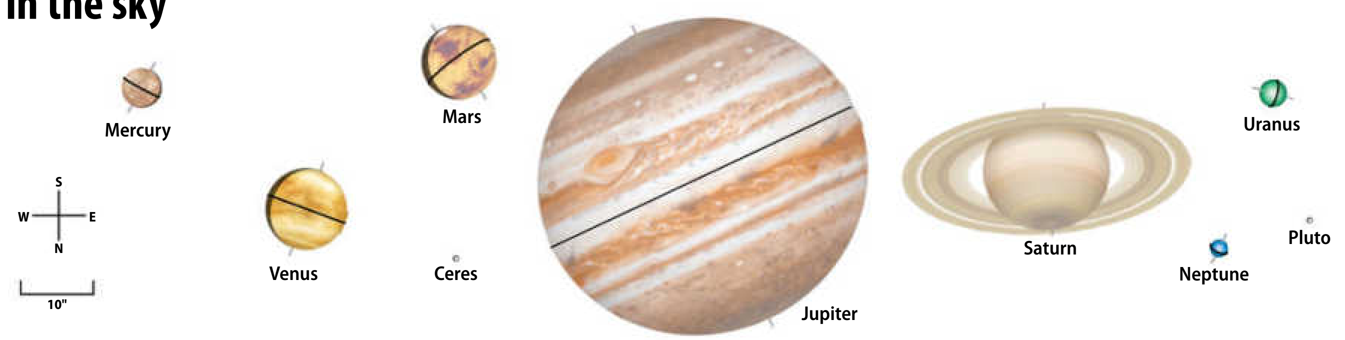
PATH OF THE PLANETS

The planets in March 2016



The planets in the sky

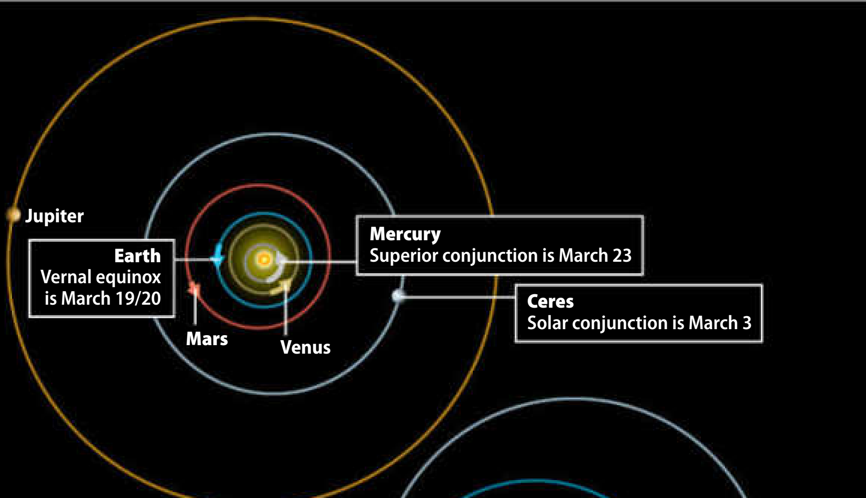
These illustrations show the size, phase, and orientation of each planet and the two brightest dwarf planets for the dates in the data table at bottom. South is at the top to match the view through a telescope.



Planets	MERCURY	VENUS	MARS	CERES	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Date	March 31	March 15	March 15	March 15	March 15	March 15	March 15	March 15	March 15
Magnitude	–1.6	–3.8	–0.1	9.0	–2.5	0.4	5.9	8.0	14.2
Angular size	5.3"	10.7"	9.9"	0.3"	44.4"	16.9"	3.4"	2.2"	0.1"
Illumination	96%	93%	91%	100%	100%	100%	100%	100%	100%
Distance (AU) from Earth	1.280	1.553	0.942	3.945	4.441	9.824	20.872	30.918	33.425
Distance (AU) from Sun	0.318	0.728	1.604	2.972	5.429	10.020	19.968	29.958	33.060
Right ascension (2000.0)	1h06.5m	22h21.3m	16h04.0m	23h28.1m	11h15.3m	17h00.3m	1h10.2m	22h46.8m	19h12.8m
Declination (2000.0)	6°52'	–11°29'	–19°35'	–12°05'	6°24'	–20°59'	6°48'	–8°37'	–20°52'

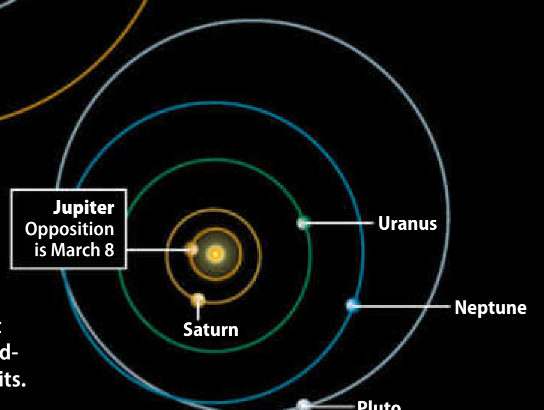
Early evening

To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.
Note: Moons vary in size due to the distance from Earth and are shown at 0h Universal Time.



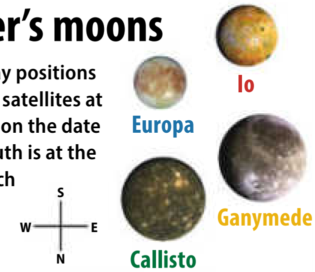
The planets in their orbits

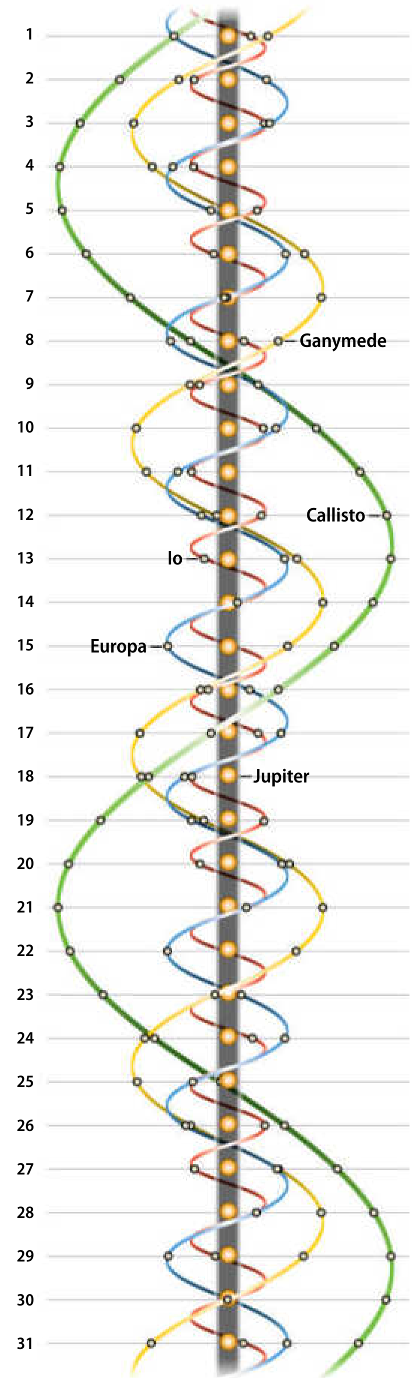
Arrows show the inner planets' monthly motions and dots depict the outer planets' positions at mid-month from high above their orbits.



Jupiter's moons

Dots display positions of Galilean satellites at 11 P.M. EDT on the date shown. South is at the top to match the view through a telescope.





ILLUSTRATIONS BY ASTRONOMY: ROEN KELLY

— *Continued from page 37*

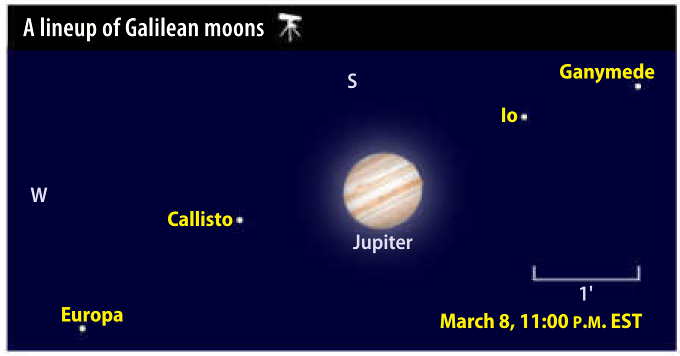
WHEN TO VIEW THE PLANETS

EVENING SKY	MIDNIGHT	MORNING SKY
Mercury (west)	Jupiter (south)	Venus (east)
Jupiter (east)		Mars (south)
Uranus (west)		Jupiter (west)
		Saturn (south)
		Neptune (east)

moon and the two shadows form a tight triangle. Europa's transit ends at 12:13 A.M. followed 14 minutes later by Io's.

As Jupiter rides high in the south shortly after midnight, **Mars** rises in the southeast. The Red Planet begins March in eastern Libra and crosses into the narrow northern section of Scorpius on the 13th. Three mornings later, it passes 0.2° northeast of the fine double star Beta (β) Scorpii.

Mars will reach opposition in May, and the approach to this milestone brings major changes in the world's appearance. The Red Planet doubles in brightness during March, rising from magnitude 0.3 to –0.5. It easily outshines Antares, Scorpius' brightest star, which lies 9° southeast



Four bright moons string out to Jupiter's east and west on the night the giant planet reaches opposition and peak visibility.

of the planet at midmonth. Note the similar colors of the two objects, which is how Antares (meaning "rival of Mars") got its name.

The changes in Mars' appearance through a telescope are no less dramatic. The planet's diameter swells from 8.7" to 11.7" during March. Seasoned Mars observers consider 10" big enough for 6-inch scopes to reveal significant surface details. The Red Planet crosses this threshold at midmonth and will remain above it through early September. (It peaks in late May

COMETSEARCH

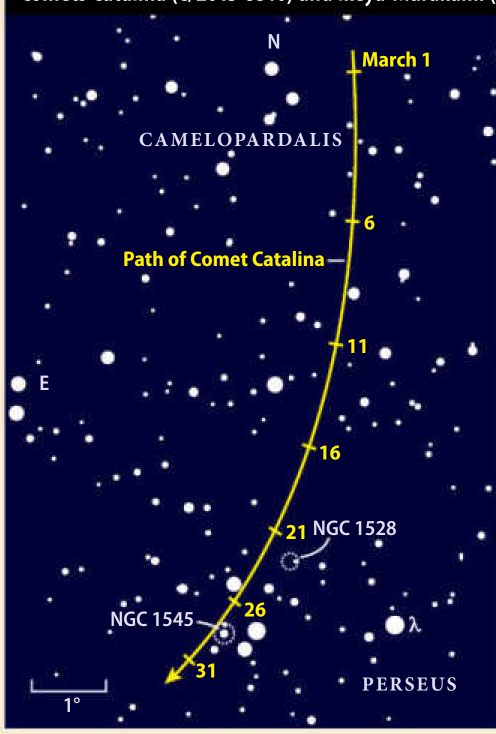
Tandem tails and traits

Observers often struggle to find one decent comet to observe. But in March, two perfectly good ones appear in the evening sky. Except for the fact that Comet Catalina (C/2013 US10) will never return to the inner solar system as it follows a hyperbolic orbit and Ikeya-Murakami (P/2010 V1) swings past the Sun every 5.4 years, these fraternal twins put on nearly identical displays this month.

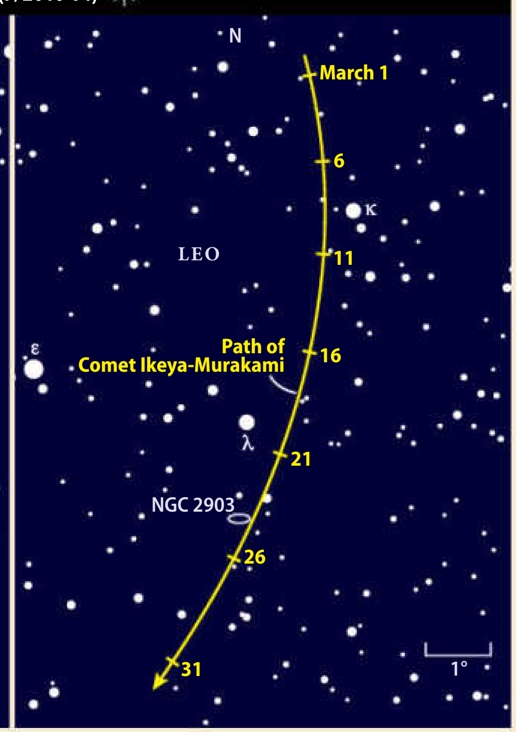
Both should glow at a modest 8th or 9th magnitude, so a 4-inch scope under a dark sky will do an admirable job revealing the transformation of their tails. In typical comets, the expelled gas and dust forms a relatively flat V-shape. But on March 24, Ikeya-Murakami's tail will appear as a slash of light as it turns edge-on to us. Coincidentally, Catalina strikes the same pose two nights later. The more nights you look, the smoother the transformation will seem. Unfortunately, a nearly Full Moon interferes with Ikeya-Murakami's crossing.

Visual observers and imagers alike should plan for the brief dark-sky window the evening of March 25. Ikeya-Murakami then lies within 15' of the bright spiral galaxy NGC 2903 in Leo. At the same time, Catalina perches halfway between the splendid star clusters NGC 1528 and NGC 1545 in the arm of Perseus.

Comets Catalina (C/2013 US10) and Ikeya-Murakami (P/2010 V1)



This 8th-magnitude dirty snowball, which recently arrived from the Oort Cloud, makes its way from Camelopardalis to Perseus during March.



This periodic visitor to the inner solar system should glow at 8th magnitude in March as it heads south near the top of Leo's Sickle asterism.

Eclipse over Indonesia

Observers in parts of Indonesia and the Pacific Ocean can witness nature's grandest spectacle — a total solar eclipse — on March 8/9. NICK HOWES

at nearly double this size.) The best views come when Mars lies highest in the south as morning twilight begins.

While spring is just starting in Earth's Northern Hemisphere, that season is well underway on Mars. This means the Red Planet's north polar cap stands out as a white patch on the limb. The most prominent dark feature is Syrtis Major. For observers in North America, this region lies near the world's western limb in early March. Because a day on Mars lasts 37 minutes longer than one on Earth, Syrtis Major rotates into better view with each passing morning. By mid-March, it stands on the eastern limb as twilight begins.

You'll also notice that Mars sports a distinct phase. On March 1, sunlight illuminates 90 percent of the Earth-facing hemisphere and the western limb appears less distinct. The phase grows to 93 percent lit by month's end.

Roughly an hour after Mars rises, **Saturn** pokes above the horizon. The ringed planet's yellowish hue contrasts nicely with ruddy Mars and Antares nearby. And at magnitude 0.4, Saturn appears intermediate in brightness between its neighbors. The ringed world has no rivals among the background stars of southern Ophiuchus.

As with Mars, the best time to view Saturn through a telescope is when it lies highest in the south as twilight starts. The gas giant's relatively bland disk measures 17" across the equator while the rings span 38" and tilt 26° to our line of sight.

Any scope immediately reveals Saturn's biggest and brightest moon, Titan. The 8th-magnitude, haze-covered satellite lies due north of Saturn on March 2 and 18 and due south of the planet on the 10th and 26th. Three 10th-magnitude moons huddle closer to the rings.

Although **Venus** rises an hour before the Sun in early March, it doesn't gain altitude quickly. Even 30 minutes later, it appears only 5° high in the east-southeast. Still, it shines at magnitude –3.9 and shows up in bright twilight. A telescope reveals its 11"-diameter disk, which appears 91 percent illuminated. By month's end, the inner planet rises just a half-hour before sunrise and will be harder to spot.

The month's most spectacular event occurs March 9 over a small part of Indonesia and the Pacific Ocean. Shortly after the Sun rises across portions of Sumatra, Borneo, and Sulawesi, the Moon passes directly in front of our star to create a **total solar eclipse**. Those who venture to the center line can witness up to three minutes of totality.

People in Hawaii will experience a substantial partial eclipse late on the afternoon of March 8 (seemingly a day early because the Moon's shadow has crossed the International Date Line). From Honolulu, the eclipse lasts from 4:33 to 6:33 P.M. HAST. Maximum occurs at 5:37 P.M., when the Moon covers 70 percent of the Sun's diameter and the pair stands 14° above the western horizon.

LOCATING**ASTEROIDS**

Staring down Leo the Lion

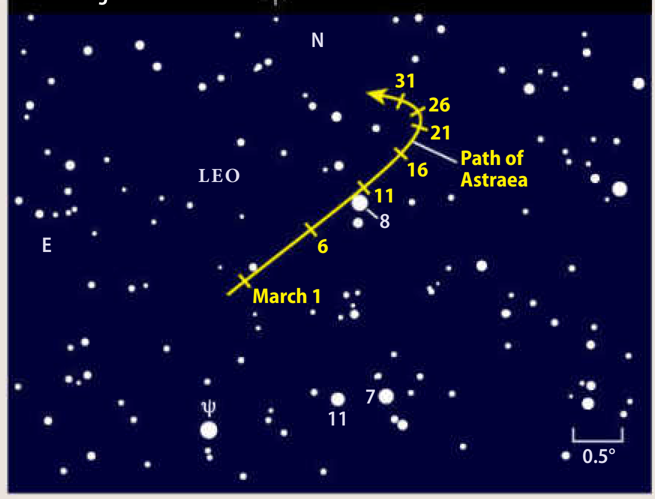
Flying high in the southeastern sky after nightfall, asteroid 5 Astraea floats in front of Leo's face. It lies a short hop from the Lion's heart, the 1st-magnitude blue-white star Regulus. Except for the nights of March 18–20, when moonlight interferes, spend some pleasant evenings striding alongside Astraea.

Your best guide star to this main-belt asteroid is 8 Leonis, a magnitude 5.7 star located 9° northwest of Regulus. Astraea remains within 1.5° of 8 Leo throughout March. Fortunately, this part of the spring sky is a long way from the Milky Way, so you should be able to tell pretty quickly which point of light you are seeking. At magnitude 9.3, Astraea glows brighter than most of the stars in this field.

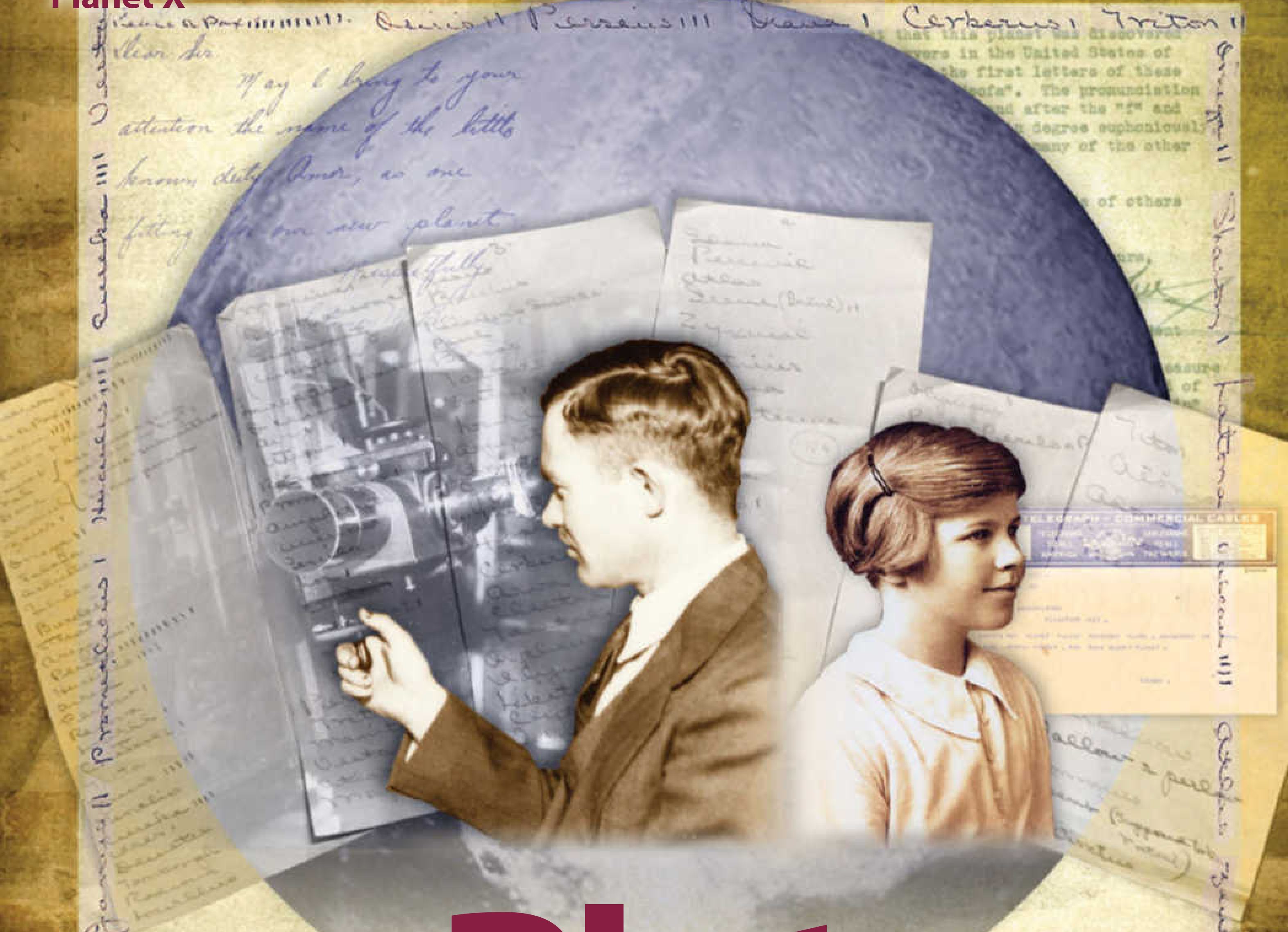
Don't get confused on the 2nd, however, when our target masquerades as the faint companion of an 8th-magnitude double star just to its north. On the 10th, this 75-mile-wide world passes 0.1° north of 8 Leo.

If you're feeling nostalgic and want to follow in the footsteps of Astraea's discoverer, German amateur astronomer Karl Hencke, you have to prove to yourself that the object moves from one night to the next. In 1845, after 15 painstaking years of comparing eyepiece views to star charts, Hencke finally laid to rest the 40-year-old idea that the solar system held only four asteroids. He found 6 Hebe 19 months later, and soon the trickle of asteroid discoveries turned into a torrent.

Astraea gets in Leo's face



As minor planet Astraea fades from magnitude 9.3 to 10.1 in March, it passes through a star-poor region surrounding 6th-magnitude 8 Leonis.



How **Pluto** got its name

The public's suggestions for naming the new planet ranged from the scientific to the personal, revealing a glimpse into the social mind-set of the day. **by Kevin Schindler and Lauren Amundson**

The staggering media attention lavished on New Horizons' flyby of Pluto last July demonstrated the public's ongoing fascination with all things Pluto. This distant neighbor from the dark and remote regions of our solar system may be physically diminutive compared with other planetary worlds, but it outshines many of them in terms of public interest and sentiment. This captivation dates back to Pluto's discovery in 1930 at Lowell Observatory, when a spellbound public overwhelmed observatory staff with letters and telegrams offering congratulations and often colorful suggestions of what to name the new planet, known only as Planet X.

This correspondence, much of it now preserved in Lowell's new Putnam Collection Center, offers invaluable insight into the issues and prevailing thoughts of the day while also revealing an intimate glimpse at the personalities of many of the individuals who submitted ideas.

One of those suggestions came from Venetia Burney, a schoolgirl from England who enjoyed learning about mythological characters. On the morning of March 14 while Venetia ate breakfast, her grandfather read to her a newspaper account of the planet's recent discovery. After thinking about the news and reflecting on her knowledge of mythology, she said Pluto, the god of the distant, cold underworld, was an appropriate name for this dark and gloomy place. Her grandfather sent her suggestion, unknown to Venetia, to the British astronomer H. H. Turner, who in turn shared it with Lowell Observatory.

This note would be one of hundreds received by the observatory but stands alone in importance, as indicated in the last paragraph of the May 1, 1930, *Lowell Observatory Circular* that served as Pluto's christening announcement to planet Earth. Lowell Director Vesto Melvin (V. M.) Slipher wrote, "It seems time now that this body should be given a name of its own. … Pluto seems very appropriate and we are proposing to the American Astronomical Society and to the Royal Astronomical Society that this name be given it. As far as we know Pluto was first suggested by Miss Venetia Burney, aged 11, of Oxford, England."

One of many

That part of the naming story is well documented in history books and often encompasses the whole tale. However, it is only the misleadingly brief and streamlined conclusion. In fact, the seven weeks between the March 13 announcement of the planet's discovery and the May 1 naming declaration were frenetic for Slipher and his colleagues. While they tried to focus on astronomical issues relating to the new planet, such as an orbit determination, the public distracted them with surging demands of what to call it.

Media bombarded Lowell staff with inquiries about the name while letters and telegrams poured in from individuals and organizations with often strongly opinionated proposals. This interest spiked even higher when a reporter misquoted Lowell trustee Roger Lowell Putnam as saying the observatory would welcome suggestions for the name. Publications from the *Boston Herald* to the *San Francisco Daily News*, *Popular Science Monthly* to *The Christian Science Monitor* carried this story, prompting even more people to join the planet-naming craze.

Newspapers and other entities also began holding contests. Monckton Dene of South Haven, Michigan, wrote four different letters to the observatory hoping to enhance his odds of winning a $5 prize. The Paramount Theater in New Haven, Connecticut, ran a naming contest in conjunction with the local paper. Paramount's advertising manager, Ben Cohen, wrote a more self-aware letter to the observatory: "The sponsors were not so presumptuous as to promise that the winning name would be given to the new planet. They did promise, however, that the winning names would be forwarded to you for your consideration. Therefore, we respectfully submit to you the contest-winning name for the new planet representing the choice of 200,000 people: Minerva." Meanwhile, Delia Grace Valancourt of Champaign, Illinois, informed the observatory that she had won

MEMORY LANE

More than two dozen of the Pluto-naming letters and telegrams, along with other Pluto-related documents and photographs from the Lowell Observatory Archives, are available for browsing in the Year of Pluto Collection at the Arizona Memory Project at **azmemory.azlibrary.gov**.


POSTAL TELEGRAPH – COMMERCIAL CABLES

TELEGRAMS TO ALL AMERICA

CABLEGRAMS TO ALL THE WORLD

OXFORD MAR 16

WLT

LOWELL OBSERVATORY

FLAGSTAFF ARIZ .

NAMING NEW PLANET PLEASE CONSIDER PLUTO . SUGGESTED BY SMALL GIRL . VEBTIA NURNEY . FOR DARK GLOOMY PLANET .

TURNER .

This telegram shows the original suggestion of the name Pluto, conceived by schoolgirl Venetia Burney and submitted via by her grandfather to Lowell Observatory.

(above transcript)
Oxford, Mar 16
WLT —
Lowell Observatory
Flagstaff, Ariz.

Naming new planet please consider Pluto, suggested by small girl Vebtia Nurney [sic], for dark gloomy planet.

Turner.

Roger Lowell Putnam was instrumental in pushing for the discovery of "Planet X," which, though predicted for erroneous reasons, nonetheless became reality with Pluto's discovery.

Kevin Schindler *has been talking Pluto for the past 20 years at Lowell Observatory, where he recently took on the role of historian.* **Lauren Amundson** *is the Lowell archivist and has handled hundreds of Pluto documents stored in the observatory's Putnam Collection Center.*

(at right transcript)
March 15, 1930.
Mr. Roger Lowell Putnam,
Springfield, Mass.

My dear Mr. Putnam,

Just another note of congratulation and one more suggestion toward a name for planet "O".

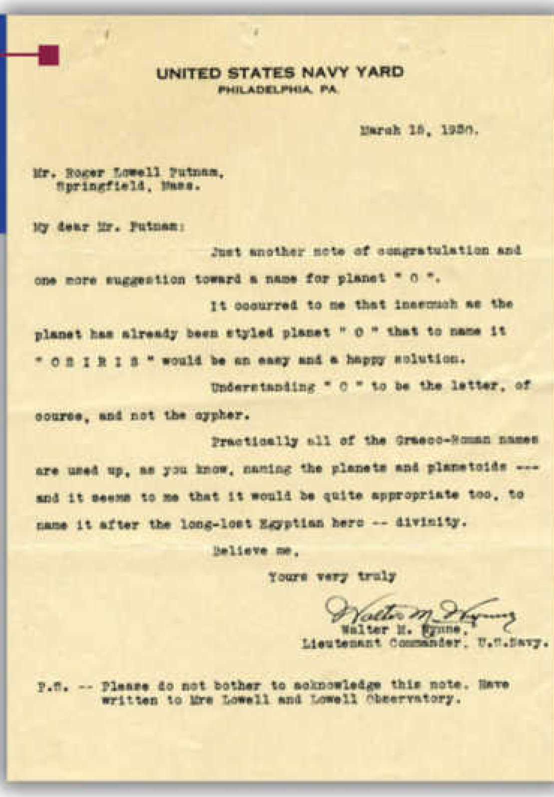
It occurred to me that inasmuch as the planet has already been styled planet "O" that to name it "OSIRIS" would be an easy and a happy solution.

Understanding "O" to be the letter, of course, and not the cypher.

Practically all of the Greco-Roman names are used up, as you know, naming the planets and planetoids — and it seems to me that it would be quite appropriate too, to name it after the long-lost Egyptian hero-divinity.

Believe me,
Yours very truly
Walter M. Wynne,
Lieutenant Commander,
U.S. Navy

P.S. — Please do not bother to acknowledge this note. Have written to Mrs. Lowell and Lowell Observatory.



UNITED STATES NAVY YARD
PHILADELPHIA, PA.

March 15, 1930.

Mr. Roger Lowell Putnam,
Springfield, Mass.

My dear Mr. Putnam:

Just another note of congratulation and one more suggestion toward a name for planet " O ".

It occurred to me that inasmuch as the planet has already been styled planet " O " that to name it " O S I R I S " would be an easy and a happy solution.

Understanding " O " to be the letter, of course, and not the cypher.

Practically all of the Graeco-Roman names are used up, as you know, naming the planets and planetoids --- and it seems to me that it would be quite appropriate too, to name it after the long-lost Egyptian hero -- divinity.

Believe me,

Yours very truly

Walter M. Wynne,
Lieutenant Commander, U.S.Navy.

P.S. -- Please do not bother to acknowledge this note. Have written to Mrs Lowell and Lowell Observatory.

Though his reasoning was flawed, astronomer William Pickering did predict the existence of a "Planet O" orbiting past Neptune ("Planet N"), similar to Lowell's Planet X.

TALLY OF THE GODS (AND OTHERS)

The following represent the **names and number of nominations** preserved in the Lowell archives, a mere fraction of the total received.

- 25 **PLUTO** Roman god of the underworld
- 17 **MINERVA** Roman goddess of knowledge
- 14 **PAX** Roman goddess of peace
- 13 **JUNO** Roman queen of the gods
- 11 **VULCAN** Roman god of fire and metalworking
- 8 **HERCULES** Roman hero
- 6 **APOLLO** Greek god of truth and music
- 6 **EREBUS** Greek god of darkness
- 6 **EUREKA** as in, "Eureka, I found it"
- 6 **PEACE**
- 5 **ATHENA** Greek goddess of knowledge
- 5 **OSIRIS** Egyptian god of the afterlife
- 5 **PERCIVAL** after Percival Lowell, who predicted the existence of the new planet

a similar challenge held by the *Chicago Herald and Examiner* for her suggestion of Athena, Minerva's Greek counterpart as the goddess of wisdom.

The proposers

Urged on by the papers and contests, the suggestions swelled. The precise number of letters and telegrams that swamped Lowell is lost to history. But the observatory received hundreds of them, with some 150 offering the name Pluto, according to a note preserved from Lowell's secretary, though most of these are nowhere to be found in the archives. With the circus-like atmosphere surrounding the naming, one can imagine much of this correspondence was simply thrown away.

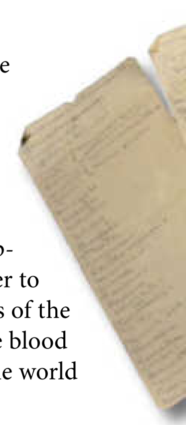
More than 250 letters remain. Many of their authors added fragments of biographical information, so we know they ranged in age from 11 to 78 and included at least 117 men and 86 women. The pool of proposers consisted of students and teachers from elementary school through college, attorneys, ministers, a United States senator, and even a lieutenant commander in the U.S. Navy.

The letters and telegrams came from 37 of the then-48 states (plus the Alaskan territory), with the most from Massachusetts (49), New York (36), and Pennsylvania (24). Suggestions also arrived from Canada, Germany, Korea, England, and Mexico. They proposed a total of 171 different names, with 13 listed at least five times. Ancient deities dominate this list, following the tradition of planet naming. Of these, six are male and four are female. Many of the latter suggestions came from the increasingly vocal female population, whose status in society was enjoying dramatic improvement at the time. One letter suggested six possibilities (Athena, Juno, Psyche, Circe, Cassandra, and Atalanta) and was signed, "Star-rover, She is not a Feminist." The author wrote, "For ages men have been the Lords of Creation. Now that women are striving for the top o' the world it would be regarded as a compliment to the sex to give the new planet a feminine name. It might encourage further exalted aspirations."

English schoolgirl Venetia Burney was just one of many to suggest a name for the newly discovered Planet X, and not even the only person to suggest the name Pluto.

A new era

Another theme of the times, the pursuit of peace, stands out thanks to the multiple suggestions of Pax and Peace. Walter Niehoff, a student at Lafayette College in Easton, Pennsylvania, compellingly captured this sentiment in his letter to the observatory: "The centuries of the past have been stained with the blood of many dreadful wars. Now the world



is experiencing a great change. We are in the beginning of an era that shall be known to our posterity as the beginning of the solution for perpetual world peace. The eyes of all men are now looking toward that goal with a hope as never before."

Some names referred to recent technological advances. Florence Wolf of Philadelphia wrote, "Why not give it a modern name? The other planets are mostly named for the ancient gods and were discovered in ancient time. As this is a modern discovery why not name it for the greatest force of the modern age, electricity?" Florence Howie of Houston offered the name Mazda to commemorate the 50th anniversary of Thomas Edison's invention of the lightbulb. William von Arx of Brooklyn liked Aeronautis because astronomers had worked to find Planet X during the era of flight. Meanwhile, Dr. E. K. Collier of Bowie, Texas, went a step further and suggested Percival-Lindbergh or Percival-Lind in honor of Percival Lowell, who spurred the hunt for Planet X, and American hero Charles Lindbergh, who still garnered headlines three years after his historic flight across the Atlantic.

Literature, both ancient and modern, inspired some suggestions. Ralph Magoffin of New York City hearkened back centuries with Vergilius, in honor of 1930 being the 2,000th anniversary of the Roman poet Virgil's works. From more contemporary times, T. Horan of Dalton, Georgia, proposed the awkward-to-pronounce Poictesme, from James Branch Cabell's then-popular but since-faded book, *Life of Manuel*.

Perhaps the most fascinating look into the public consciousness of 1930 can be seen in the hodgepodge of names that defy any other classification. Howard Carter's 1922 discovery of the tomb of King Tutankhamun was still in the mind of Josephine T. of Harbert, Michigan, when she suggested Shu, the Egyptian god of the atmosphere, "as recently found by Mr. Howard Carter in the annex of the Tutankhamun tomb." Even Prohibition, begun in 1920 but winding down by 1930, made an appearance in the name game. Philip Bowman of Annapolis, Maryland, suggested Bacchus, the Roman god of wine-making, as "typical of the age we live in." *The Literary Magazine* suggested, "For this notable cosmic catch completing the big-league planetary nine, it would be fitting to call the starry outfielder Babe Ruth." Ruth was then near the end of his baseball career but still a larger-than-life figure.

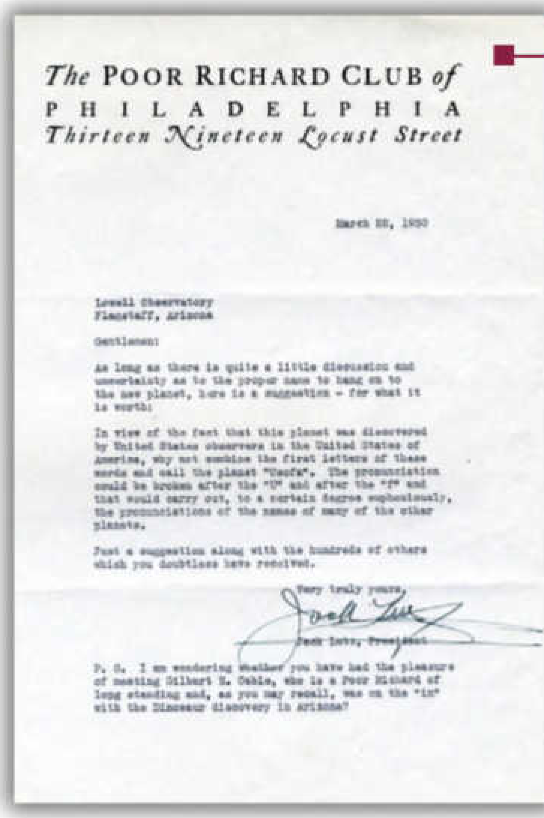
Many of the names honored individuals associated with Planet X, particularly Lowell. These include simply Lowell or Percival but also combinations such as Percilo, Perlo, and Perlow (the first letters of his first and last name), and Percius (Percival and his country, the United States). Gale Dismukes of Juneau, Alaska, wanted to honor the discoverer of the new planet, Clyde Tombaugh, with the name Tom Boy. She even included a poem:

"The Planet Speaks"

"Tom Boy" "Tom Boy"
Let it be my name
Surely Mr. Tombaugh
Beats in this game.

Playing "Hide and seek"
I often have thought
I, should like to be
discovered
By one self-taught.

Let the joyous tidings
Ring the world around
"Tom Boy" "Tom Boy"
The latest Planet found."


The POOR RICHARD CLUB *of*
P H I L A D E L P H I A
Thirteen Nineteen Locust Street

March [illegible], 1930

Lowell Observatory
Flagstaff, Arizona

Gentlemen:

As long as there is quite a little discussion and uncertainty as to the proper name to hang on to the new planet, here is a suggestion - for what it is worth:

In view of the fact that this planet was discovered by United States observers in the United States of America, why not combine the first letters of these words and call the planet "Usofa". The pronunciation could be broken after the "U" and after the "f" and that would carry out, to a certain degree euphoniously, the pronunciations of the names of many of the other planets.

Just a suggestion along with the hundreds of others which you doubtless have received.

Very truly yours,

Jack Lutz, President

P. S. I am wondering whether you have had the pleasure of meeting Gilbert E. Gable, who is a Poor Richard of long standing and, as you may recall, was on the "in" with the Dinosaur discovery in Arizona?

Since it was the only planet discovered in the United States, some contributors were driven to patriotic suggestions.

(at left transcript)
Lowell Observatory
Flagstaff, Arizona

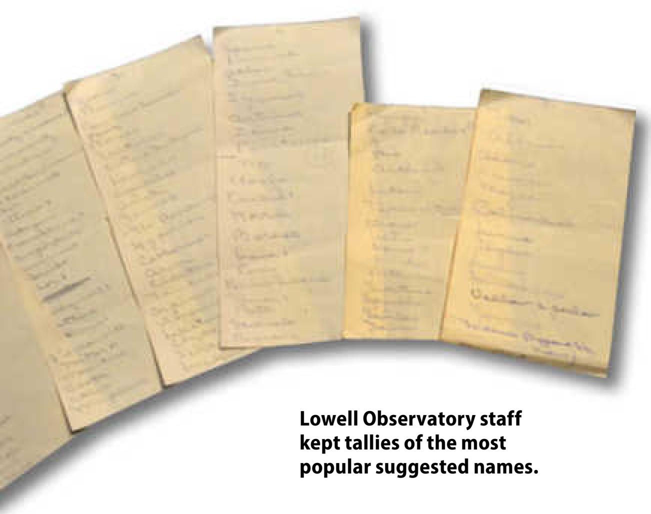
Gentlemen:

As long as there is quite a little discussion and uncertainty as to the proper name to hang on to the new planet, here is a suggestion — for what it is worth:

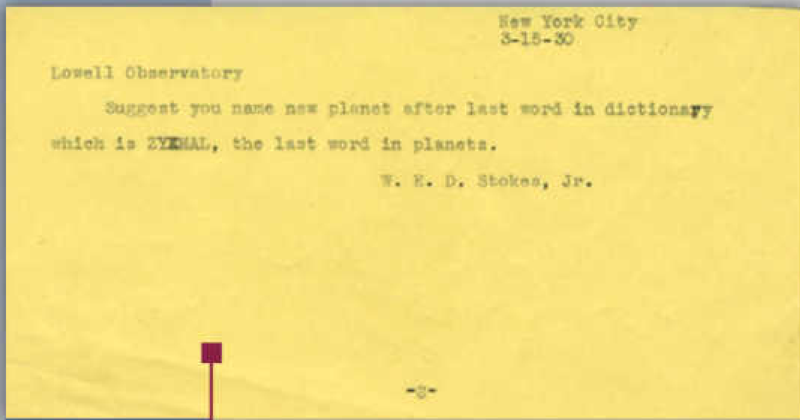
In view of the fact that this planet was discovered by United States observers in the United States of America, why not combine the first letters of these words and call the planet "Usofa". The pronunciation could be broken after the "U" and after the "f" and that would carry out, to a certain degree euphoniously, the pronunciations of the names of many of the other planets.

Just a suggestion along with the hundreds of others which you doubtless have received.

Very truly yours,
Jack Lutz, President


Lowell Observatory staff kept tallies of the most popular suggested names.


NASA/JPL-CALTECH/SwRI


New York City
3-15-30

Lowell Observatory

Suggest you name new planet after last word in dictionary which is ZYKMAL, the last word in planets.

W. E. D. Stokes, Jr.

-2-

Some contributors offered clever ideas.

(above transcript)
New York City
3-15-30

Lowell Observatory

Suggest you name new planet after last word in dictionary which is ZYKMAL, the last word in planets.

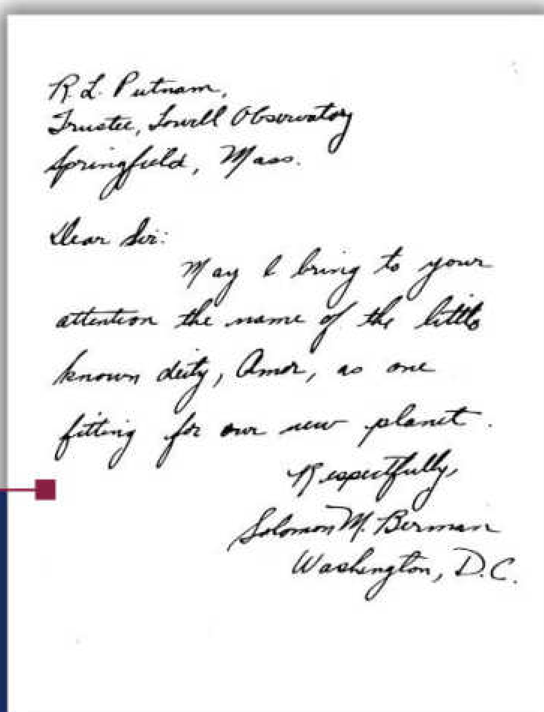
W. E. D. Stokes, Jr.

(at left transcript)
R. L. Putnam,
Trustee, Lowell Observatory,
Springfield, Mass.

Dear Sir:

May I bring to your attention the name of the little known deity, Amor, as one fitting for our new planet.

Respectfully,
Solomon M. Berman
Washington, D.C.


R. L. Putnam,
Trustee, Lowell Observatory
Springfield, Mass.

Dear Sir:

May I bring to your attention the name of the little known deity, Amor, as one fitting for our new planet.

Respectfully,
Solomon M. Berman
Washington, D.C.

A prescient suggestion, given the newly discovered heart shape on Pluto, came from Solomon Berman.

Clyde Tombaugh, Pluto's discoverer, peers through the "blink comparator" he used to identify tiny, dim Pluto on the photographic plates.

Astronomers found more to love about Pluto in the detailed images captured during the July 2015 flyby, including the heart-shaped Tombaugh Regio. NASA/JPL-CALTECH/SwRI

One of the cutest ideas came from Karl Underhill of New Hampshire. He wrote, "If I had discovered the new trans-Neptunian planet I would name it Jean after my two-year baby girl. I do not know the definition of the name Jean but it means everything to me. This letter is not a crank."

Making the call

While many of these suggestions undoubtedly made for good reading, the Lowell staff ultimately chose Pluto. Putnam gave a press statement explaining the decision to go with a Roman god, in accordance with the other planets. He said, "There have been many suggestions which have been weighed and sifted, and suitable ones were narrowed down to three — Minerva, Cronus, and Pluto." Minerva was the staff's first choice but since an asteroid already bore the goddess's name, they decided on Pluto, "the god of the regions of darkness where X holds sway." Putnam pointed out that Pluto's two mythological brothers, Jupiter and Neptune, were already represented by solar system planets. "Now one is found for him [Pluto] and he at last comes into his inheritance in the outermost regions of the Sun's domain."

Eighty-five years after Pluto's discovery and naming, public fascination with this icy body remains strong. These days, instead of suggesting names for the body itself, people are thinking of names for Pluto's geographical and geological regions, again pulling ideas from mythology, pop culture, and the real scientists and visionaries involved with the Pluto system. What will future generations glean from the current wave of naming choices? Whether because Pluto was long considered the only planet discovered in the United States, or because so many people regard it as an underdog, it remains beloved in the hearts of many in the population. Given this warm regard, plus the heart-shaped region the New Horizons team imaged and later dubbed "Tombaugh Regio," perhaps Solomon Berman of Washington, D.C., writing to the observatory in 1930, offered the best and most prescient name: Amor.

15 STELLAR SOFTWARE PACKAGES

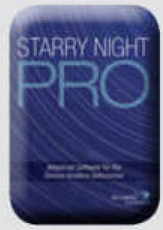
These programs will bring your astronomy experience into the digital age. **by Tom Trusock**

Every amateur astronomer these days knows the value of meshing astronomy with some kind of computer, whether you favor a smartphone, tablet, or good old PC of the Microsoft, Apple, or Linux variety. Software is available for everything, from creating star charts and logging observations, to telescope and observatory control, to planetarium and simulation software that can replicate events in the night sky. There's even software that allows you to visit other planets and places in space. Hundreds of options are out there. Let's look at a few of my favorites.

1

$49.95–$249.95 depending on version

Starry Night



Platforms: Windows, Macintosh
Website: http://astronomy.starrynight.com
Classification: Observation planning, telescope control, simulation
Summary: Billed as the world's most realistic astronomy software, Starry Night is one of the most complete packages available. Starry Night is available in four different tiers, each at a different price. At $50, Starry Night Complete Space and Astronomy Pack is for the beginner looking to get into astronomy and learn more about the subject, while the $250 Starry Night Pro Plus 7 contains a more complete database of stars and deep-sky objects, several all-sky CCD mosaics, telescope control, and a Maxim DL plug-in for the imagers out there. It serves as a great observing aid and companion.

FREE

Cartes du Ciel-SkyChart

2

Platforms: Windows, Macintosh, Linux, Raspberry Pi
Website: www.ap-i.net/skychart/en/start
Classification: Observation planning, telescope control
Summary: For those of you looking for an observing planning tool, this is one of the best packages out there, especially factoring in the price. Written by Patrick Chevalley, SkyChart is a program dedicated to one main purpose: creating maps for your astronomical sessions. It does an excellent job. Very configurable, with gigabytes of additional (optional) data, it's available for the low price of free. This is one program every amateur astronomer should take a look at. For many, it will be all they really need.

$49–$329

3

TheSkyX

Platforms: Windows, Macintosh
Website: www.bisque.com/sc/
Classification: Observation planning, telescope control, simulation
Summary: Without a doubt, TheSkyX professional edition is the gorilla in the room when it comes to one-stop shopping for your astronomical observing needs. For those without their own robotic observatory, the $329 price tag might be a bit of overkill, but if you want to have complete remote control of your observatory, this is the way to go. It, too, is priced at different levels according to your needs.

FREE

4

Stellarium

Platforms: Windows, Macintosh, Linux
Website: www.stellarium.org
Classification: Simulation
Summary: Stellarium is an absolutely gorgeous night-sky simulator, suitable for simulating the views with naked eye, binoculars, and a small telescope. While photorealistic, it's more than just a pretty face, as testified to by its use in classrooms and planetaria. Well supported by the community, it's perfect for puttering around on cloudy nights when no real observing can get done. The data and options are a bit limited compared with some competitors, but there's no beating the price.

FREE

5

Virtual Moon Atlas

Platforms: Windows, Macintosh, Linux
Website: www.ap-i.net/avl/en/start
Classification: Lunar atlas
Summary: Patrick Chevalley (Cartes du Ciel) and Christian Legrand collaborated on Virtual Moon Atlas. It's an extensive database that couples images from spacecraft and the very best earthbound observers with high-resolution modern and historical textures. If you're an observer with even a casual interest in the Moon, you owe it to yourself to have this on your computer.

6

SkyTools 3

Platform: Windows
Website: www.skyhound.com
Classification: Observation planning and logging, telescope control
Summary: As a visual observer, if I had to pick only one package, it would be SkyTools 3. Built on an exhaustive database of deep-sky objects, SkyTools allows you to instantly see which targets are best placed and at what times for your observing session. From that list, it's then easy to get detailed information on the target visibility, generate finder charts, and log observations. SkyTools is an infinitely refinable and fantastic tool that no serious amateur astronomer should be without.

$39.95–$179.95

7

Space Engine

Platform: Windows
Website: http://en.spaceengine.org
Classification: Simulation, exploration
Summary: Developed by Russian astronomer Vladimir Romanyuk, Space Engine uses a combination of real astronomical catalogs and procedurally generated data (where catalogs are unavailable) to create a 3-D planetarium of the entire universe. If you've ever had a touch of wanderlust, this might be just the thing to pass away hours when you'd like to be observing but can't. Users are free to move about the entire cosmos, viewing and visiting New General Catalog (NGC) and Index Catalog (IC) objects, verified extrasolar planetary systems, black holes, aurorae, and much more.

FREE

PERSONAL COMPUTERS

FREE

8 WorldWide Telescope

Platforms: Windows, online
Website: http://worldwidetelescope.org
Classification: Virtual telescope
Summary: If you're trapped inside on a cloudy night but are still interested in what the recorded universe has to offer, head over to WorldWide Telescope. The software is designed to display on everything from personal computing devices up to public planetaria. You can be guided on a pre-recorded journey of discovery or strike out on your own. With a bevy of online catalogs and data types, only the sky is the limit. You can run the software locally or in a browser; I found it to be much more responsive when run locally. Beware: If you have a slower data connection, a little bit of patience will go a long way here.

9 Eye & Telescope

$89.99

Platform: Windows
Website: www.eyeandtelescope.com
Classification: Observation planning, virtual telescope, logging
Summary: Eye & Telescope tries to do something no other program does — namely, it attempts to show the observer what his chosen target will look like from his own site through his own telescope. There are some caveats, but in general the software succeeds surprisingly well.

10 Kerbal Space Program

$40

Platforms: Windows, Macintosh, Linux
Website: http://kerbalspaceprogram.com/en
Classification: Space program simulation, game
Summary: If you've ever dreamed of developing your own space program, this one's for you. Set on the fictional planet of Kerbin, Kerbal Space Program gives you a Lego box worth of rocket parts and some adventurous Kerbal astronauts, and sets you free to explore a solar system with several real-world analogs. This program is so popular that Squad (the developer) and NASA have collaborated to simulate an Asteroid Capture Mission. More recently, Squad and the B612 Foundation added an official Asteroid Day mod, incorporating the proposed Sentinel Mission to look for asteroids that threaten Earth. While not the easiest game on the market, it still manages to make learning (and failure) fun. I'd say it's not rocket science, but…

MOBILE

FREE (FULL VERSION $3)

11 Aurora Notifier

Platform: Android
Website: http://play.google.com
Classification: Informational
Summary: Aurora Notifier uses Google messaging to let you know when the northern lights are visible from your location. You can configure the strength of the storms you want to be notified about and the alert times. Additionally it provides an illustration of the present state of the aurora on a 3-D globe. While there are packages that provide more information and options, this is one of my favorites because of its design and simplicity.

Tom Trusock *is a veteran observer who lives in Ubly, Michigan.*

FREE (WITH OPTIONAL IN-APP PURCHASE)

12

Starmap 2

Platform: iOS
Website: www.star-map.fr
Classification: Observation planning, simulation, telescope control
Summary: Now available in version 2.0, Starmap lets you try before you buy. In-app purchases let you tailor the app to exactly what you need. I'm particularly fond of the planning tools. You can plumb many different catalogs, but one of my favorite options gives you a list of the best objects for the evening, complete with a filterable chart that easily tells you when an object is visible and at its best. Those who are fond of the visibility charts in SkyTools will find these extremely useful as well. New for version 2 is Starmap Stories, designed to help you find objects in the sky and learn something about them. Offering a different take on the mobile planetarium, Starmap 2 has a lot to like.

FREE (WITH OPTIONAL IN-APP PURCHASE)

13

Exoplanet

Platform: iOS
Website: http://exoplanetapp.com
Classification: Exoplanet catalog
Summary: If exoplanets are your thing, then this is the app for you. The app includes each planet's discovery method, star charts, and visualizations of exoplanets and their associated habitable zones. Updated on a near-daily basis, this remains hands down the best exoplanet app in the mobile arena.

14

SkySafari 4

Platforms: Android, iOS
Website: http://skysafariastronomy.com
Classification: Observation planning, simulation, telescope control
Summary: SkySafari is the undisputed champ in the mobile arena. Here, the question is not so much if you should purchase, but which version. I will warn you: Only the most casual astronomers will be satisfied with the basic version and 220-item deep-sky database. The next step up shows you 31,000 deep-sky objects, including the full set of NGC and IC objects. For those wanting nothing but the best, consider an upgrade to the Pro version, which adds 740,000 galaxies, and solar system objects including all known asteroids and comets. As an aside, Celestron contracted with SkySafari's creators to offer a free version called SkyPortal. SkyPortal is light on features and tailored toward use with Celestron telescopes, but it's definitely worth a look.

$2.99–$39.99

15

NASA

Platforms: Android, Kindle Fire, iOS
Website: www.nasa.gov/centers/ames/iphone/index.html
Classification: Informational
Summary: The NASA app allows you to track satellites, get information about current missions, watch live streams of NASA TV and the High Definition Earth Viewing experiment on the ISS, find launch information, and stay updated on the latest news about space and space exploration. It's a great way to keep all of your NASA information in one place.

FREE

Plan now for the 2017 ECLIPSE

Follow these 25 common sense tips, and you'll be ready to rock on eclipse day.

by Michael E. Bakich

ARE YOU GETTING EXCITED YET? As you read this, we're less than a year and a half away from the biggest celestial event of our lives — the total solar eclipse that will cross the continental United States August 21, 2017. Lots of people already have decided where they want to view the spectacle. (If you haven't, don't worry. I'll be writing about primo locations in our June issue.)

Many hopeful eclipse watchers are making it the centerpiece of their 2017 summer vacations. And even if your travel plans occur earlier, it's not a bad idea to view this event like you would a vacation.

To that end, I've gathered 25 common sense tips that will help you get into the proper mindset. Once you've done that, you're ready to set a plan in motion that will let you have the time of your life.

1 Take eclipse day off

You may think a year and a half is a bit of a long lead-time, and, unless you work for a magazine called *Astronomy*, it may be. The point to consider is that August 21, 2017, may turn out to be the most popular vacation-day request in history. If not now, figure out the earliest date that makes sense for you to request August 21 as a vacation day, and mark it on your calendar.

KEN WILSON

2 Make it a long weekend

The eclipse occurs on a Monday. Lots of related activities will occur on Saturday and Sunday in locations touched by the Moon's inner shadow. Find out what they are, where they're being held, and which you want to attend, and make a mini-vacation out of the eclipse.

3 Watch the weather

Meteorologists study a chaotic system. Nobody now can tell you with certainty the weather a location will experience on eclipse day. So, don't get too tied up in the predictions of cloud cover you'll see for that date. Many don't distinguish between "few" (one-eighth to two-eighths of the sky covered), "scattered" (three-eighths to four-eighths), "broken" (five-eighths to seven-eighths) clouds, and overcast. One online repository of knowledge I can recommend is Canadian meteorologist Jay Anderson's Eclipser website (www.eclipser.ca).

4 Get involved

If your interests include celestial happenings and public service, consider volunteering with a group putting on an eclipse event. You'll learn a lot and make some new friends in the process. Don't worry if you don't know eclipses inside and out. After a year of helping prepare, you will.

5 Attend an event

You'll enjoy the eclipse more if you hook up with like-minded people. If you don't see any special goings-on, call your local astronomy club, planetarium, or science center. Any person you talk to is sure to know of eclipse activities. Travel companies, like *Astronomy*'s partner TravelQuest, also offer trips that will let you experience the full social impact of the eclipse.

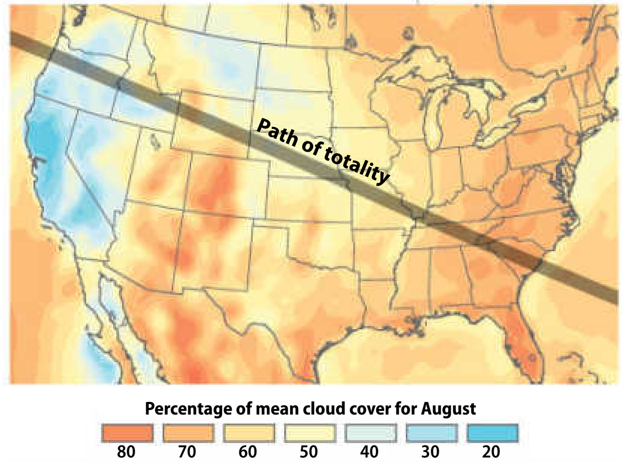
6 Stay flexible

Unless you're certain August 21 will be clear, don't do anything you can't undo in a short time. For example, let's say you're taking a motor home to a site. You connect it to power, extend the awnings, set up chairs, and more.

But if it's cloudy six hours, three hours, or even one hour before the eclipse starts, you're going to want to move to a different location. Think of the time you would have saved if you had waited to set up. Also, the earlier you make your decision to move, the better. Just imagine what the traffic might be like on eclipse day.

7 Concentrate on the sky

Totality will be the shortest two and a half minutes of your life. All your attention should be on the Sun. Anything else is a waste. And be considerate of those around you. Please, no music.



3

This eclipse-track map shows the average afternoon August cloudiness derived from 22 years of satellite observations. GRAPHICS: JAY ANDERSON; DATA: CIMSS/NOAA/UW-MADISON

8 Watch for the approach of the Moon's shadow

If your viewing location is at a high elevation, or even at the top of a good-sized hill, you may see the Moon's shadow approaching along the ground from the northwest to the southeast. This sighting isn't easy because as the shadow crosses the U.S., it is moving at a minimum of Mach 1.5 (1,151 mph, 1,852 km/h) and a maximum of Mach 3.5 (2,685 mph, 4,321 km/h). Another way to spot our satellite's shadow is as it covers thin cirrus clouds if any are above your site. I hope you don't experience clouds, but if you do, you'll be surprised how fast the shadow moves.

9 Notice it getting cooler?

Point a camera that records video at a digital thermometer and a watch, both of which you previously attached to a white piece of cardboard. Start recording video 15 or so minutes before totality and keep

5

Heading off with a group organized by a tour provider will allow you to experience the social impact of the eclipse. MICHAEL E. BAKICH

10

Although these solar viewing glasses from Rainbow Symphony resemble sunglasses, they are not sunglasses. The only object you'll see through them is the Sun. RAINBOW SYMPHONY

16

Pictures of friends really help you relive eclipses even years after the events. This shot of Shadow Winter demonstrates the proper use of eclipse glasses. MICHAEL E. BAKICH

shooting until 15 minutes afterward. The results may surprise you.

10 Get a filter in advance

Cardboard eclipse "glasses" with lenses of optical Mylar cost less than $2. Such a device — it's not a toy — will let you safely look directly at the Sun anytime.

Another safe solar filter is #14 welder's glass, which also will cost you about $2. Wanna look cool at the eclipse? Buy goggles that will hold the welder's glass. I've even seen people wearing whole helmets. Either those or goggles serve one purpose — you won't need to hold the filter, so you can't drop it. The downside is comfort. August 21 will be warm across the U.S. and, in many locations, humid.

11 View the 360° sunset

A couple of times during totality, take a few seconds to tear your eyes away from the sky and scan the horizon. You'll see sunset colors all around you because, in effect, those locations are where sunset (or sunrise) is happening.

12 Pee before totality

Yes, I could have phrased this more politely, but you needed to read it. This tip, above any other on this list, could be the most important one for you. Don't wait until 10 minutes before totality to start searching for a bathroom. Too much is happening then. Make a preemptive strike 45 minutes prior.

13 No filter? You can still watch the eclipse

Except during totality, we never look at the Sun. But what if you've forgotten a filter? You can still watch by making a pinhole camera. It can be as simple as two pieces of paper with a tiny hole in one of them. (Try to make the hole as round as you can, perhaps with a pin or a sharp pencil.) Line up the two pieces with the Sun so the one with the hole is closest to it. The pinhole will produce a tiny image, which you'll want to have land on the other piece of paper. Moving the two pieces farther apart will enlarge the Sun's image but will also lessen its brightness. Work out the best compromise.

14 Bring a chair

In all likelihood, you'll be at your viewing site several hours before the eclipse starts. You don't really want to stand that whole time, do you? Are friends coming? Provide a chair for everyone.

15 Don't forget sunscreen

Most people who go outside during the summer know this. Remember, you'll be standing around or sitting outside for hours. You may want to bring an umbrella for some welcome shade. And if you see someone who has forgotten sunscreen, please be a peach and share. This is true solar safety.

16 Take lots of pictures

Be sure to capture images of your viewing site and the people with whom you shared this great event. If you have a camera that records video, I suggest you mount it on a tripod, position it about 25 feet (8 meters) away, aim it toward your group, and record from 15 minutes before totality to 15 minutes after. You'll document all your reactions and the darkening and brightening of your site. (Note: If your camera automatically compensates for darkness, disable that feature.)

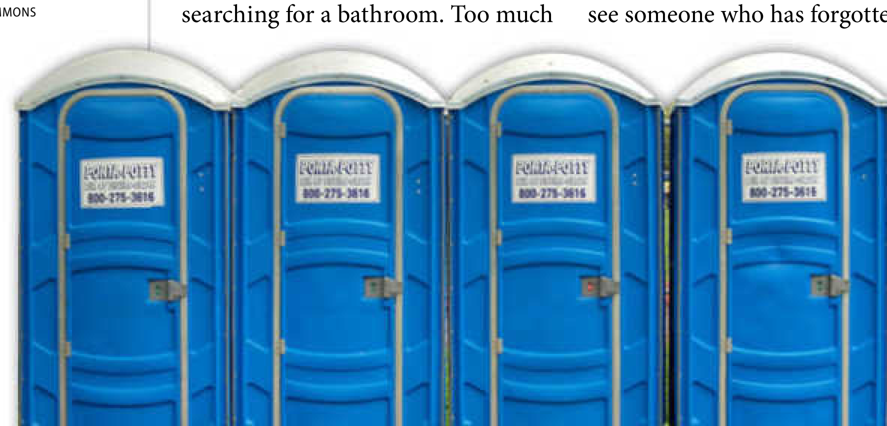
17 Regard totality as sacred

In the August 1980 issue of *Astronomy* magazine, author Norm Sperling contributed a "Forum" titled "Sperling's 8-second Law" in which he tries to convey how quickly totality seems to pass. I'll just quote the beginning here. "Everyone who sees a total solar eclipse remembers it forever. It overwhelms the senses, and the soul as well — the curdling doom of the onrushing umbra, the otherworldly pink prominences, and the ethereal pearly corona. And incredibly soon, totality terminates.

"Then it hits you: 'It was supposed to last a few minutes — but that couldn't have been true. It only seemed to last eight seconds!'"

18 Bring snacks and drinks

You're probably going to get hungry — and in the summer in the



12

At organized events, sweet relief will be a short walk away. Finish your business well before totality. DAVID SHANKBONE/WIKIMEDIA COMMONS

U.S., you definitely will get thirsty — waiting for the eclipse to start. Unless you set up next to a convenience store, bring some light snacks and plenty to drink. Remember, even if you're attending a sponsored event, there's no guarantee water vendors won't run out. Some places will have many times the number of people they expect. Don't trust someone else with your comfort.

19 Remember that no one will have seen totality

If you're planning an event or a family gathering related to the eclipse, consider this: Statistically, 100 percent of the people you encounter — to a high degree of accuracy — will never have experienced darkness at noon. You will be the expert.

20 Invite someone with a solar telescope

If you're hosting a private shindig, make sure someone brings a telescope with a solar filter. While it's true that you don't need a scope to view the eclipse, having one there will generate buzz, and it will help Sun-watchers get the most from their experience. And you (or the scope's owner) can point out sunspots, irregularities along the Moon's edge, and more. You can even take a look at Venus.

21 Experience totality all by yourself

The 2017 eclipse, plus the events leading up to it, will combine to be a fabulous social affair. Totality itself, however, is a time that you should mentally shed your surroundings and focus solely on the sublime celestial dance above you. You'll have time for conversations later.

22 Schedule an after-eclipse party or meal

Regarding No. 21, once the eclipse winds down, you'll be on an emotional high for hours, and so will everyone else. There's no better time to get together with family and friends and just chat. Fun!

23 Record your memories

Sometime shortly after the eclipse, when the event is still fresh in your mind, take some time to write, voice-record, or make a video of your memories, thoughts, and impressions. A decade from now — or, more specifically, just before the next U.S. total solar eclipse in 2024 — such a chronicle will help you relive this fantastic event. Have friends join in, too. Stick a video camera in their faces and capture 30 seconds from each of them. You'll smile each time you watch it.

24 Don't be in a rush afterward

Traffic, or the new term I have for what we all will experience on eclipse day — gridlock — will be horrendous after the event at some locations. And the sooner you try to leave, the worse it will be. Relax. Let the part of the eclipse between third and fourth contacts play out. Many people will view this portion as "what we saw before totality, but in reverse." For this section, however, all the tension will be gone.

25 Don't photograph it

This tip may sound strange coming from the photo editor of the best-selling astronomy magazine on Earth. But I've preached it to thousands of people whom I've led to far-flung corners of our planet to stand under the Moon's shadow. True, few of them have thanked me afterward.

But I can tell you of upward of a hundred people who have told me with trembling voices, "I wish I'd followed your advice. I spent so much time trying to center the image and get the right exposures that I hardly looked at the eclipse at all." How sad is that?

And here's another point: No picture will capture what your eyes will reveal. Trust me, I've seen them all. Only the top 0.1 percent of photographers ever has come close. And you — no offense — with your off-the-shelf SLR or point-and-shoot pocket camera are not one of them.

Finally, why would you even consider looking down and fiddling with a camera when you could be looking up at all that heavenly glory? This eclipse will — at maximum — last 160 seconds. That's it, friends. If your camera isn't doing what you think it should, you're going to lose valuable time adjusting it. There will be plenty of pics from imagers who have viewed a dozen of these events.

So just watch. Watch your first eclipse with your mouth agape, where your only distraction is occasionally wiping tears of joy from your eyes. I promise that you will not be disappointed.

Now, relax

Once you come up with a course of action that lets you stay flexible with some of the details, you'll feel a lot better as August 21, 2017, approaches. And the family and friends that you include surely will say, like Bill Murray's character Dr. Peter Venkman in the movie *Ghostbusters*, "I love this plan. I'm excited to be a part of it!"

Michael E. Bakich *is a senior editor of* Astronomy. *He will be conducting a massive public viewing party for the eclipse at Rosecrans Memorial Airport in St. Joseph, Missouri. See www.fpsci.com for details.*

20 Amateur astronomer John Volk shared views of the Sun through his telescope during the November 13, 2012, total solar eclipse in Australia. Note the approved solar filter covering the front of his scope. MICHAEL E. BAKICH

25 *Astronomy* Contributing Editor Mike Reynolds has seen 16 total solar eclipses. You haven't seen any, so just watch the spectacle and photograph your next one. MICHAEL E. BAKICH

Run a non-Messier marathon

For a new adventure, challenge yourself to see these 109 objects in a single night.

by Michael E. Bakich

NGC 1365
Don Goldman

I REMEMBER THE TIME before I worked at *Astronomy* magazine. I would eagerly anticipate each issue and scan every one for new observing challenges — especially lists. I don't know why, but I love lists. The Messier objects? Dozens of times. Caldwell? Check. Herschel objects? Been there, done that.

So, as I started to think about how to write another guide to the Messier marathon, an idea came to me: I'd propose a non-Messier marathon specifically for amateur astronomers who have run several of the traditional ones from the Crab Nebula (M1) to spiral galaxy M109. I'm not going to take up a lot of space describing it, but I will list my criteria.

My marathon contains 109 deep-sky objects handpicked by me with no repetition of Messier or Caldwell items. I didn't include any double stars. I chose objects visible around the March equinox and accessible from most of the continental United States, so all declinations are north of -40° and no right ascensions are around 0 hours (where the Sun lives at this time of year). Finally, all objects are brighter than 12th magnitude. OK, all but two of them, but I know medium-size scopes can reveal both of those from a dark site.

I didn't have nearly enough pages to describe all the objects, so I picked a few in each category. You'll find a complete table on pages 60 and 62. Start with the objects at the top of the list and work down. If you do, you'll find yourself starting in the west (after sunset) and progressing eastward.

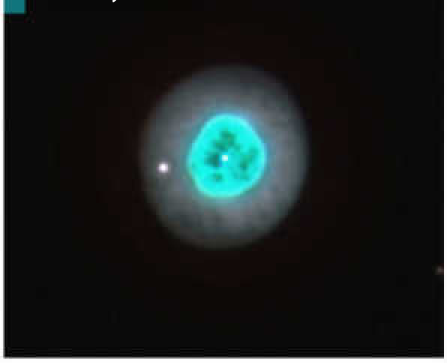
You'll have the whole night, so spend a little time examining each entry before you make a checkmark and jump to the next object. And yes, it's totally fine if you use a go-to drive. I will. I want to spend most of my time observing these treats, not proving that I can find them. Good luck!

Personal favorites

The first object on the list is a perfect target for a medium-size scope: Mirach's Ghost, also known as **NGC 404**, in Andromeda. Amateur astronomers call this magnitude 10.3 elliptical galaxy Mirach's Ghost because it lies only 6.8' from 2nd-magnitude Mirach (Beta [β] Andromedae). As you might imagine, a 10th-magnitude galaxy next to that bright a star is pretty difficult to see. Use high magnification to increase the contrast between the galaxy and star. NGC 404 looks round and bright with an intense center.

Stay in the Princess' constellation, and look a bit more than 2° north-northwest of the Double Cluster in Perseus (NGC 869 and NGC 884) for the nearby open cluster **Stock 2**. This object appeared on a list of open clusters compiled by German astronomer Jürgen Stock. Stock 2 spans a full degree but shines at magnitude 4.4, so

CLEOPATRA'S EYE (NGC 1535)
Adam Block/Mount Lemmon SkyCenter/ University of Arizona



Michael E. Bakich *is a senior editor of* Astronomy *who will be conducting a huge free public eclipse watch at Rosecrans Memorial Airport in St. Joseph, Missouri, on August 21, 2017.*

small telescopes do a good job displaying it, if you keep the magnification below 50x. Expect to see a loose collection of about 50 stars between 8th and 10th magnitudes.

Another object I think you'll like lies far to the south. The powerful radio source astronomers call Fornax A (**NGC 1316**) is a bright (magnitude 8.9) galaxy you can find 1.4° south-southwest of magnitude 6.4 Chi^1 (χ^1) Fornacis.

This galaxy's spiral arms wrap so tightly around its core that it appears elliptical through most telescopes. NGC 1316 isn't circular, however. It's about half as long as it is wide, and it orients northeast to southwest. You'll see the broad central region surrounded by a thick halo.

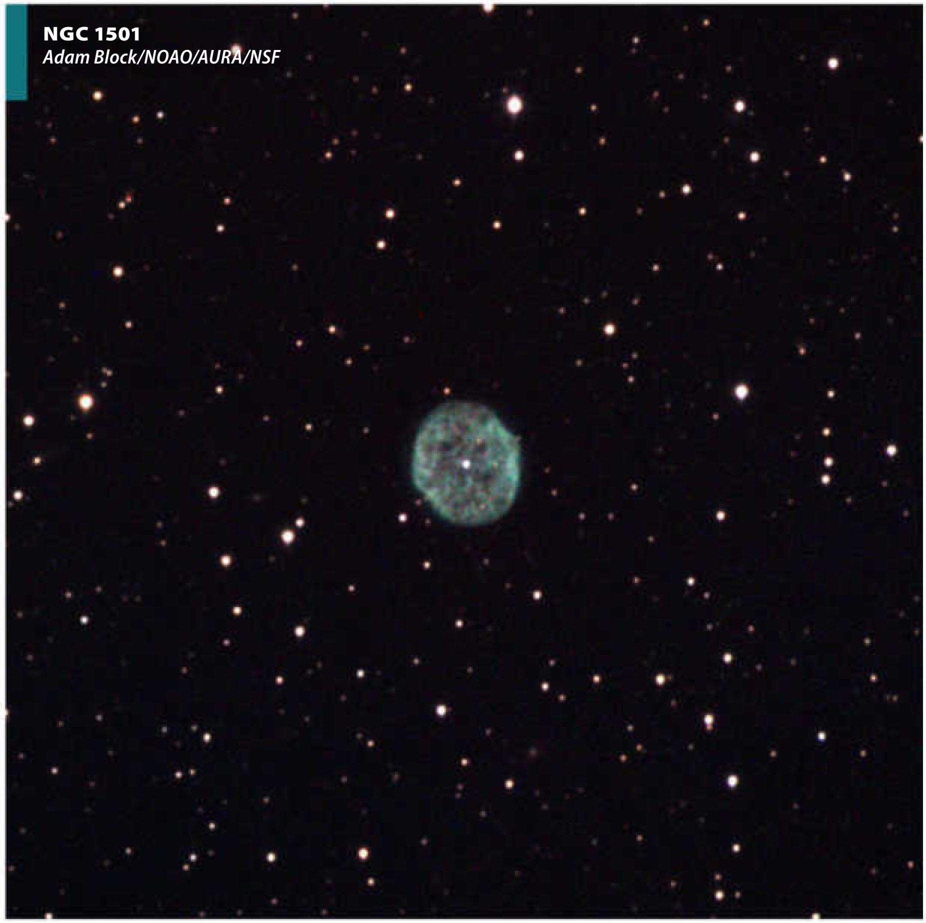
While you're in Fornax, take a look at the best example of a barred spiral galaxy in the sky — **NGC 1365**. Although it's bright (magnitude 9.3), it isn't all that easy to star-hop to. To do so, first find a triangle of three faint stars, magnitude 6.4 Chi^1, magnitude 5.7 Chi^2, and magnitude 6.5 Chi^3 Fornacis. From Chi^2, which is the brightest, move 1.3° east-southeast.

Through even a 4-inch telescope at a dark site, you'll see NGC 1365's bar shape and brighter central region. Increase the magnification, and notice how the bar near the core appears dimmer than it does farther out. An 8-inch scope shows the spiral arms. The brighter one extends northward from the bar's west end. The other arm, only slightly fainter, appears somewhat blotchy, revealing huge star-forming regions within it.

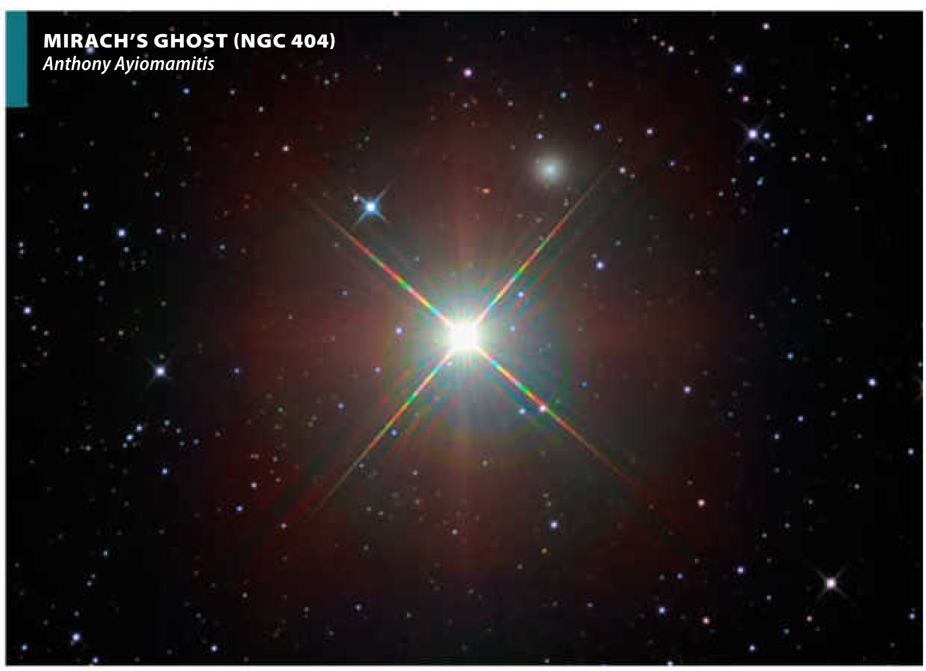
Our next object, planetary nebula **NGC 1501**, lies 6.9° west of magnitude 4.0 Beta Camelopardalis. Amateur astronomers call this object the Oyster Nebula. A 10-inch telescope shows a circular disk. Through a 16-inch scope at magnifications above 350x, however, you'll note that the planetary is ever-so-slightly oval in an east-west orientation. The magnitude 14 central star is easier to see than its lofty number suggests. It peeks through a slightly darker center that suggests the presence of a thick ring structure. Through the larger instrument, the planetary's face appears patchy, with several small dark areas visible.

Another pretty planetary, Cleopatra's Eye (**NGC 1535**), lies 4° east-northeast of magnitude 3.0 Zaurak (Gamma [γ] Eridani). It's nice and bright (magnitude 9.6) and takes high powers well. Through a 6-inch telescope, NGC 1535 has a sharply defined disk surrounded by a faint envelope. Double that aperture to 12 inches, and you'll begin to pick up this object's color. Now, crank the magnification past 300x, and you'll observe a dark hollow around the central star. At this aperture and power, you'll note that the contrast between the sharp inner disk and the fainter outer shell is at its maximum.

My next pick, which sharp-eyed observers can spot without optical aid from a dark site, is the open cluster Hagrid's Dragon (**NGC 2301**). This object covers a circle 15' wide and lies 5.1° west of magnitude 4.2 Delta (δ) Monocerotis. It's a great object through any telescope, and wide-angle views show a rich surrounding star field. A 6-inch scope reveals some 50 stars. Crank the power past 200x, and look for a



NGC 1501
Adam Block/NOAO/AURA/NSF



MIRACH'S GHOST (NGC 404)
Anthony Ayiomamitis

NON-MESSIER MARATHON OBSERVING LIST

Object	Con.	R.A.	Dec.	Mag.	Size	Type	Other name
NGC 404	Andromeda	1h09m	35°43'	10.3	6.1' by 6.1'	E	Mirach's Ghost
NGC 584	Cetus	1h31m	–6°52'	10.5	4.1' by 2'	E	The Little Spindle Galaxy
NGC 654	Cassiopeia	1h44m	61°53'	6.5	5'	OC	
NGC 659	Cassiopeia	1h44m	60°40'	7.9	6'	OC	The Yin-Yang Cluster
NGC 772	Aries	1h59m	19°01'	10.3	7.3' by 4.6'	S	The Fiddlehead Galaxy
Stock 2	Cassiopeia	2h15m	59°16'	4.4	60'	OC	
NGC 925	Triangulum	2h27m	33°35'	10.1	12.0' by 7.4'	S	
IC 1805	Cassiopeia	2h33m	61°27'	—	60'	E	The Heart Nebula
NGC 1023	Perseus	2h40m	39°04'	9.3	8.6' by 4.2'	S	The Perseus Lenticular
Stock 23	Camelopardalis	3h16m	60°02'	6.5	14'	OC	Pazmino's Cluster
NGC 1291	Eridanus	3h17m	–41°08'	8.5	11.0' by 9.5'	S	The Snow Collar Galaxy
NGC 1316	Fornax	3h23m	–37°12'	8.9	11.0' by 7.6'	S	Fornax A
NGC 1333	Perseus	3h29m	31°25'	—	6' by 3'	R	The Embryo Nebula
NGC 1365	Fornax	3h34m	–36°08'	9.3	8.9' by 6.5'	S	
NGC 1501	Camelopardalis	4h07m	60°55'	11.5	52"	P	The Oyster Nebula
NGC 1514	Taurus	4h09m	30°47'	10.9	114"	P	The Crystal Ball Nebula
NGC 1535	Eridanus	4h14m	–12°44'	9.6	18"	P	Cleopatra's Eye
NGC 1647	Taurus	4h46m	19°07'	6.4	40'	OC	The Pirate Moon Cluster
NGC 1788	Orion	5h07m	–3°21'	—	5' by 3'	R	The Fox Face
NGC 1857	Auriga	5h20m	39°21'	7.0	5'	OC	
Collinder 464	Camelopardalis	5h22m	73°00'	4.2	120'	OC	
IC 418	Lepus	5h28m	–12°42'	9.3	12"	P	The Raspberry Nebula
NGC 1981	Orion	5h35m	–4°26'	4.2	28'	OC	The Coal Car Cluster
NGC 2129	Gemini	6h02m	23°19'	6.7	6'	OC	
NGC 2169	Orion	6h08m	13°58'	5.9	6'	OC	"37" Cluster
NGC 2175	Orion	6h10m	20°30'	—	40' by 30'	E	The Monkey Face Nebula
9–12 Gem	Gemini	6h18m	23°38'	—	1°	A	
NGC 2146	Camelopardalis	6h19m	78°21'	10.6	5.4' by 4.5'	BS	The Dusty Hand Galaxy
NGC 2264	Monoceros	6h41m	9°53'	3.9	20'	OC	The Christmas Tree Cluster
NGC 2281	Auriga	6h49m	41°04'	5.4	14'	OC	
NGC 2301	Monoceros	6h52m	0°28'	6.0	15'	OC	Hagrid's Dragon
NGC 2336	Camelopardalis	7h27m	80°11'	10.4	6.4' by 3.3'	BS	
IC 2177	Monoceros	7h05m	–10°38'	—	120' by 40'	E	The Seagull Nebula
NGC 2353	Monoceros	7h15m	–10°18'	7.1	20'	OC	Avery's Island
NGC 2359	Canis Major	7h19m	–13°12'	—	9' by 6'	E	Thor's Helmet
NGC 2367	Canis Major	7h20m	–21°53'	7.9	5'	OC	
NGC 2371–2	Gemini	7h26m	29°29'	11.3	54" by 35"	P	The Double Bubble Nebula
NGC 2440	Puppis	7h42m	–18° 13'	9.4	14"	P	The Albino Butterfly Nebula
Melotte 71	Puppis	7h38m	–12° 04'	7.1	9'	OC	
NGC 2451	Puppis	7h45m	–37° 58'	2.8	45'	OC	The Stinging Scorpion
NGC 2539	Puppis	8h11m	–12° 50'	6.5	21'	OC	The Dish Cluster
NGC 2546	Puppis	8h12m	–37°37'	6.3	70'	OC	The Heart and Dagger Cluster
NGC 2683	Lynx	8h53m	33°25'	9.8	8.4' by 2.4'	S	The UFO Galaxy
NGC 2685	Ursa Major	8h56m	58°44'	11.1	4.9' by 2.4'	S	The Helix Galaxy
NGC 2841	Ursa Major	9h22m	50°59'	9.3	8.1' by 3.5'	S	
NGC 2903	Leo	9h32m	21°30'	9.0	12.0' by 5.6'	S	
Leo I	Leo	10h09m	12°18'	10.2	12.0' by 9.3'	DS	
NGC 3184	Ursa Major	10h18m	41°25'	9.8	7.8' by 7.2'	S	The Little Pinwheel Galaxy
NGC 3227	Leo	10h24m	19°52'	10.3	6.9' by 5.4'	S	
NGC 3344	Leo Minor	10h44m	24°55'	9.9	6.9' by 6.4'	S	The Sliced Onion Galaxy
NGC 3521	Leo	11h06m	–0°02'	9.0	12.5' by 6.5'	S	
NGC 3621	Hydra	11h18m	–32°49'	8.9	9.8' by 4.6'	S	The Frame Galaxy
NGC 3953	Ursa Major	11h53m	52°19'	9.8	6.9' by 3.6'	BS	
NGC 4111	Canes Venatici	12h07m	43°04'	10.7	4.4' by 0.9'	S	
NGC 4216	Virgo	12h16m	13°09'	10.0	7.8' by 1.6'	S	The Silver Streak Galaxy

— Continued on page 62

double star dead-center. The two components have magnitudes of 8.0 and 8.8.

Head to Canis Major next and target Thor's Helmet (**NGC 2359**), a 9' by 6' cosmic bubble sculpted by radiation from a type of luminous, massive star called a Wolf-Rayet star. It lies 4.3° northeast of magnitude 4.1 Muliphain (Gamma Canis Majoris). The nebula responds well to narrowband filters. Through an 11-inch scope, you'll see the circular central area and the helmet's two "wings." The brightest part measures 1' wide and extends to the south approximately 4'.

I really like the Double Bubble Nebula (**NGC 2371–2**), a twin-lobed planetary that glows at 11th magnitude in Gemini. This object's common name comes from its unusual appearance: Two rounded puffs of gas lie side by side, with each lobe getting brighter toward the middle.

You'll find it 1.7° north of magnitude 3.8 Propus (Iota [ι] Geminorum). When you're first hunting NGC 2371–2, use at least an 8-inch scope and low power. This object measures 54" by 35", making it nearly as big as the Ring Nebula (M57) in Lyra. An Oxygen-III eyepiece filter definitely helps.

My next target lies in a constellation — Lynx — even more difficult to find than some deep-sky objects. The obscure star group lies due north of Cancer and stretches to the northwest from there. The UFO Galaxy (**NGC 2683**) is a spiral, and, at magnitude 9.8, a relatively bright one. You can spot it through a 3-inch telescope from a dark observing site. To pull out its details, however, you'll need a bigger scope.

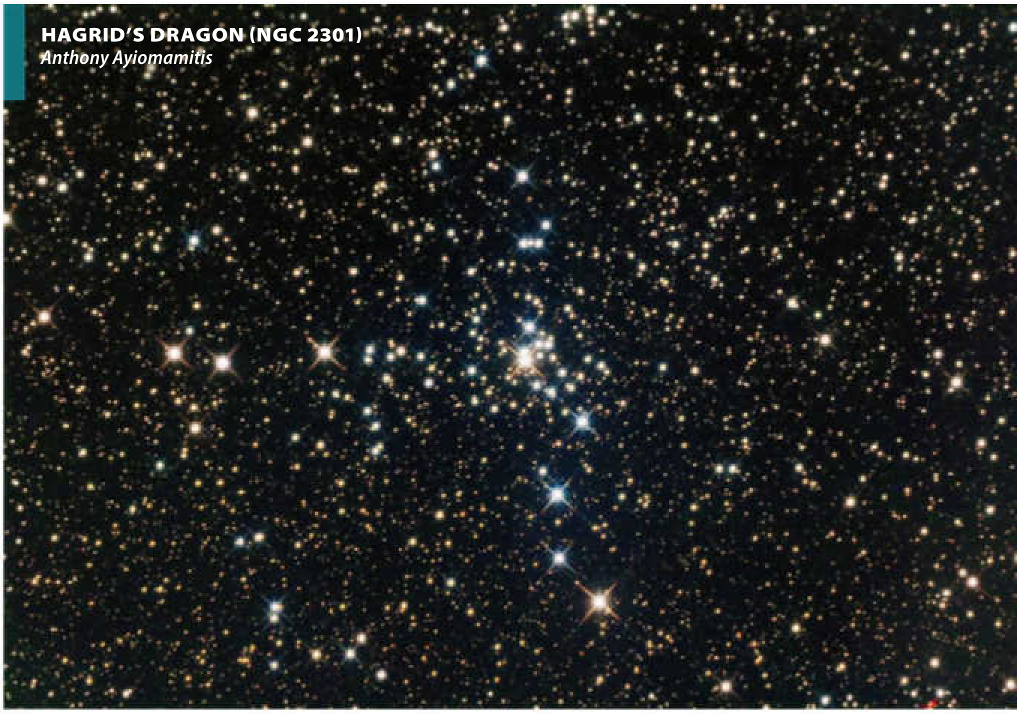
NGC 2683 is a classic edge-on spiral that orients northeast to southwest. The faint spiral arms begin to show alternate dark and bright patches called mottling through an 11-inch telescope. Through even larger scopes, you'll notice that the northeastern arm extends a bit farther than the southwestern one.

One of my lesser-known favorites is magnitude 9.3 spiral galaxy **NGC 2841**. What a gorgeous object! This galaxy tilts southeast to northwest and displays a classic disk appearance. Its nucleus is wide and bright. Through an 8-inch telescope, you'll see several dark regions within the tightly wound spiral arms, but the arms themselves are tough to see even at high powers. You'll find this treat 1.8° west-southwest of magnitude 3.2 Theta (θ) Ursae Majoris.

The next target is another favorite of mine. It demonstrates that a celestial object can be easy to find, but really difficult to observe its details. What makes it easy to find is its location: Leo I lies only 20' due north of magnitude 1.3 Regulus (Alpha [α] Leonis). But that brilliant star's glare through the eyepiece also makes Leo I difficult to see. At a dark site, an 8-inch telescope at 150x reveals a faint mist that appears uniformly bright. Whatever you do, keep Regulus out of the field of view.

Now point your scope only 8° from the celestial pole to the Baby Eskimo Nebula (**IC 3568**), a planetary that glows at magnitude 10.6. Its tiny inner core appears bright, but you'll need at least a 10-inch telescope and 200x to see the 13th-magnitude central star. A slightly fainter shell surrounds the core. You'll also spot a 12th-magnitude star just 15" to the west. Whatever scope you view this object through, be sure to use as high a magnification as the sky will allow.

The next object, Iota's Ghost (**NGC 5102**), sits far to the south but only 0.3° east-northeast of magnitude 2.8 Iota Centauri. This spiral galaxy appears relatively bright because it lies some 11 million



HAGRID'S DRAGON (NGC 2301)
Anthony Ayiomamitis

THE UFO GALAXY (NGC 2683)
Adam Block/Mount Lemmon SkyCenter/ University of Arizona

— Continued from page 60

Object	Con.	R.A.	Dec.	Mag.	Size	Type	Other name
NGC 4361	Corvus	12h25m	–18°47'	10.9	45"	P	
NGC 4490	Canes Venatici	12h31m	41°38'	9.8	6.4' by 3.3'	BS	The Cocoon Galaxy
NGC 4517	Virgo	12h33m	0°07'	10.4	9.9' by 1.4'	S	
NGC 4526	Virgo	12h34m	7°42'	9.6	7' by 2.5'	S	The Hairy Eyebrow Galaxy
IC 3568	Camelopardalis	12h33m	82°33'	10.6	10"	P	The Baby Eskimo Nebula
NGC 4535	Virgo	12h34m	8°12'	10.0	7.0' by 6.4'	S	The Lost Galaxy
NGC 4605	Ursa Major	12h40m	61°37'	10.9	6.0' by 2.4'	S	The Faberge Egg Galaxy
NGC 4656-7	Canes Venatici	12h44m	32°10'	10.4	14' by 3'	I	The Hockey Stick
NGC 5053	Coma Berenices	13h16m	17°42'	9.9	10.5'	G	
NGC 5102	Centaurus	13h22m	–36°38'	8.8	9.8' by 4.0'	S	Iota's Ghost
IC 972	Virgo	14h04m	–17°15'	13.9	43"	P	Abell 37
NGC 5466	Boötes	14h06m	28°32'	9.2	11.0'	G	
NGC 5634	Virgo	14h30m	–5°59'	9.5	5.5'	G	
NGC 5907	Draco	15h16m	56°20'	10.3	11.5' by 1.7'	S	
NGC 5897	Libra	15h17m	–21°01'	8.4	12.6'	G	The Ghost Globular
NGC 5985	Draco	15h40m	59°20'	11.1	5.3' by 2.9'	S	
NGC 5986	Lupus	15h46m	–37°47'	7.5	9.8'	G	
NGC 6058	Hercules	16h04m	40°41'	12.9	42"	P	
IC 4593	Hercules	16h12m	12°04'	10.7	42"	P	The White-Eyed Pea
NGC 6072	Scorpius	16h13m	–36°14'	11.7	40"	P	
NGC 6144	Scorpius	16h27m	–26°02'	9.0	9.3'	G	
NGC 6210	Hercules	16h45m	23°49'	8.8	14"	P	The Turtle Nebula
NGC 6293	Ophiuchus	17h10m	–26°35'	8.2	7.9'	G	
NGC 6309	Ophiuchus	17h14m	–12°55'	11.5	18"	P	The Box Nebula
NGC 6334	Scorpius	17h20m	–35°51'	—	35' by 20'	E	The Cat's Paw Nebula
NGC 6337	Scorpius	17h22m	–38°29'	12.3	48"	P	The Cheerio Nebula
Barnard 72	Ophiuchus	17h24m	–23°38'	—	4'	D	The Snake Nebula
NGC 6369	Ophiuchus	17h29m	–23°46'	11.4	>30"	P	The Little Ghost
IC 4665	Ophiuchus	17h46m	5°43'	4.2	70'	OC	The Little Beehive
NGC 6441	Scorpius	17h50m	–37°03'	7.2	7.8'	G	The Silver Nugget Cluster
NGC 6445	Sagittarius	17h49m	–20°01'	11.2	34"	P	The Box Nebula
NGC 6503	Draco	17h49m	70°09'	10.2	7.3' by 2.4'	S	The Lost in Space Galaxy
NGC 6520	Sagittarius	18h03m	–27°54'	7.6	6'	OC	The Castaway Cluster
NGC 6544	Sagittarius	18h07m	–25°00'	7.5	9.2'	G	The Starfish Cluster
NGC 6559	Sagittarius	18h10m	–24°07'	—	8'	E	
Barnard 86	Sagittarius	18h03m	–27°53'	—	5' by 5'	D	The Ink Spot
NGC 6572	Ophiuchus	18h12m	6°51'	8.1	18"	P	The Emerald Nebula
NGC 6633	Ophiuchus	18h28m	6°34'	4.6	27'	OC	The Captain Hook Cluster
IC 4756	Serpens (Cauda)	18h39m	5°27'	4.6	52'	OC	Graff's Cluster
NGC 6712	Scutum	18h53m	–8°42'	8.2	7.2'	G	
IC 1295	Scutum	18h55m	–8°50'	11.7	86"	P	
NGC 6723	Sagittarius	19h00m	–36°38'	6.8	11.0'	G	The Chandelier Cluster
NGC 6741	Aquila	19h03m	–0°27'	11.4	6"	P	The Phantom Streak
NGC 6781	Aquila	19h18m	6°33'	11.4	109"	P	
NGC 6818	Sagittarius	19h44m	–14°09'	9.3	48"	P	The Little Gem
NGC 6819	Cygnus	19h41m	40°11'	7.3	5'	OC	The Fox Head Cluster
NGC 6866	Cygnus	20h04m	44°09'	7.6	7'	OC	The Frigate Bird Cluster
NGC 6905	Delphinus	20h22m	20°07'	11.1	39"	P	The Blue Flash
NGC 6910	Cygnus	20h23m	40°47'	7.4	10'	OC	
NGC 6940	Vulpecula	20h35m	28°18'	6.3	31'	OC	Mothra
NGC 7008	Cygnus	21h01m	54°33'	10.7	83"	P	The Fetus Nebula
NGC 7026	Cygnus	21h06m	47°51'	10.9	21"	P	The Cheeseburger Nebula
NGC 7027	Cygnus	21h07m	42°14'	25	8.8"	P	The Magic Carpet Nebula
NGC 7129	Cepheus	21h43m	66°06'	11.5	7'	OC	The Small Cluster Nebula

Key: Con. = Constellation; R.A. = Right ascension (2000.0); Dec. = Declination (2000.0); Mag. = Magnitude; A = Asterism; BS = Barred spiral galaxy; D = Dark nebula; DS = Dwarf spheroidal galaxy; E = Emission nebula; G = Globular cluster; I = Irregular galaxy; OC = Open cluster; P = Planetary nebula; R = Reflection nebula; S = Spiral galaxy

light-years away. Unfortunately, that distance also means its light spreads out quite a bit, so it doesn't show as many details as other similarly sized objects. Through an 8-inch telescope, look for a bright central region surrounded by a large oval halo twice as long as it is wide. Oh, and you'll get your best views if you move Iota out of the field of view.

About an hour after you target Iota's Ghost (which probably will be between 2 A.M. and 3 A.M.), head to a seemingly related object, the Ghost Globular (**NGC 5897**), the best deep-sky object in Libra. To find it, travel exactly 8° southeast of Zubenelgenubi (Alpha Librae). Because this object lies 40,000 light-years away, its brightest stars glow at only magnitude 13.

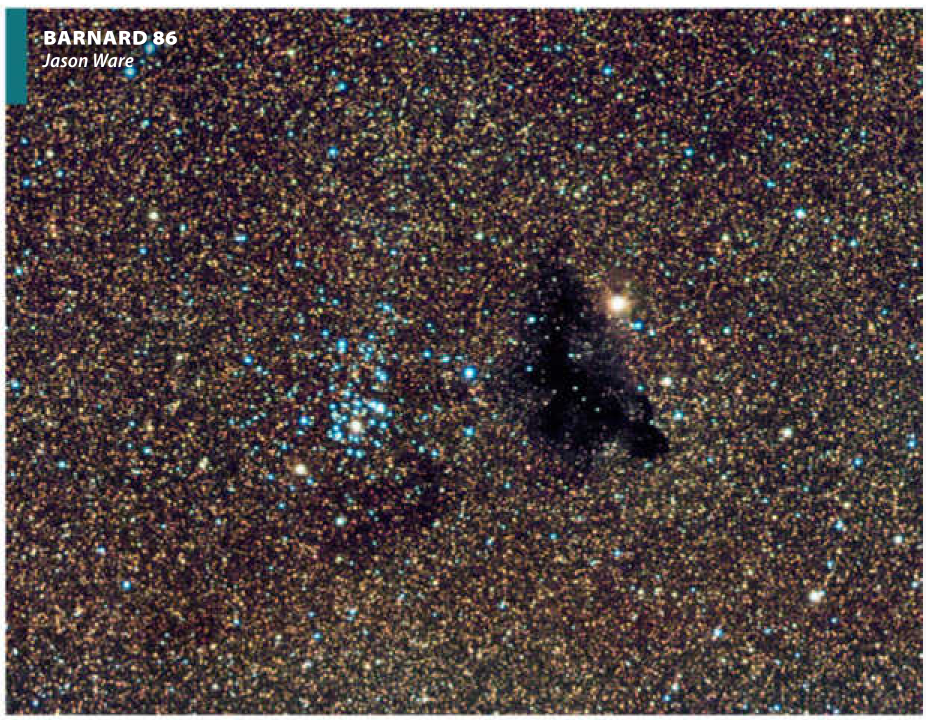
Still, enough stars group together here that the cluster is easy to spot through 11x80 binoculars. The most striking aspect of NGC 5897 is how loosely its stars concentrate toward the center.

Through an 8-inch telescope at a dark site, you'll see only the brightest dozen or so stars against a faint, comet-like glow. Through a 13-inch scope, the star count rises to 50. If you're lucky enough to view NGC 5897 through a 20-inch scope, crank the power past 200x. You'll see stars scatter widely across the cluster's center with little apparent concentration.

Some named deep-sky objects look exactly like their namesakes. The Dumbbell Nebula and the North America Nebula come to mind. Add one more — the Cat's Paw Nebula (**NGC 6334**) in Scorpius. The Paw ranks among the Milky Way's largest star-forming regions. It comprises five individual nebulous patches in a circular area. The brightest measures 6' across and contains a 9th-magnitude star. It lies on the southeastern end of the complex. Because this object is larger than the Full Moon, you'll need a wide-field combination to view it all. Another approach is to crank up the power a bit, screw a nebula filter into your eyepiece's barrel, and view each of the five areas separately. To find NGC 6334, look 3° west-northwest of Shaula (Lambda [λ] Scorpii).

My next pick is a dark nebula called the Ink Spot, also known as **Barnard 86** (B86). If you're uncertain how to target it, just aim for NGC 6520, a nearby star cluster. Together, these objects present a wonderful contrast. Through an 8-inch telescope, you'll see about 30 stellar members of NGC 6520 against a bright background of distant stars. No such background exists for B86. Its starless, irregular form stands out against myriad faint stars. Look for the orange magnitude 6.7 double star WDS HDS2541 on B86's western edge — a nice complement to the scene.


THE GHOST GLOBULAR (NGC 5897)
Dean Salman


BARNARD 86
Jason Ware

The 109th object on my list is the Small Cluster Nebula (**NGC 7129**), which you'll find 2.6° northwest of magnitude 4.4 Xi (ξ) Cephei. It's a star cluster, but it also includes a star-forming region that contains emission and reflection nebulosity. The cluster carries the NGC designation. The three nebulous regions are IC 5132, IC 5133, and IC 5134.

A 6-inch telescope will reveal the cluster, a collection of a dozen or so stars. To see the nebulae, however, you'll need to step up to at least a 10-inch scope under a dark sky. Most of the nebulosity is of the reflection type, so no filter helps.

The tally

How many objects did you see? I'd love to hear about your first non-Messier marathon. You can contact me at mbakich@astronomy.com. When I get enough reports, I'll post the results in a blog.

We test Tele Vue's DeLite eyepieces

Select these eyepieces to enhance your observing without ruining your credit. **by Tom Trusock**

Tele Vue's DeLite eyepiece series offers significant savings over other high-quality eyepiece lines. The company launched the DeLites with three focal lengths.
COURTESY TELE VUE OPTICS

Eyepieces are a visual astronomer's window to the universe. And history shows that Tele Vue led the revolution in high-quality wide-field eyepieces with its introduction of the Nagler line in the early 1980s. Company founder Al Nagler was the driving force and principal optical designer on all eyepieces until the introduction of the Ethos line, when protégé Paul Delechiaie stepped up to the plate. Delechiaie went on to design the Delos line and, most recently, the DeLite line.

Tele Vue targeted the DeLites, introduced just before the 2015 Northeast Astronomy Forum convention, at observers looking for an economical high-end eyepiece that's small and light yet provides diffraction-limited performance, high contrast, and generous eye relief.

Details

These 1¼" eyepieces are initially available in three focal lengths: 7mm, 11mm, and 18.2mm. Priced at $250 each, they feature a 62° apparent field of view, 20mm of eye relief, an adjustable locking eye guard, and compatibility with Tele Vue's astigmatism correction system, the Dioptrix.

The DeLites are well suited for use in large binoculars or binoviewers due to their reasonable weights, 7.3, 7.1, and 7.6 ounces (207, 201, and 215 grams, respectively). All feature the Tele Vue barrel safety undercut

Tom Trusock *loves testing new equipment, attending star parties, and observing for the fun of it from his home in Ubly, Michigan.*

to help prevent an errant eyepiece from falling to the ground.

When I test eyepieces, it's important to me to use them in a variety of telescopes so I can understand what aberrations the telescope adds to the design. Through the years, I've seen amateurs blame specific aberrations on eyepiece design that were the fault of the telescope. Always remember, we deal with an optical system. Because of this, I'm careful to review eyepieces in various telescopes I am already familiar with. For this review, I used an 18-inch f/4.5 Newtonian reflector (equipped with the Tele Vue Paracorr), a 3.6-inch f/7 apochromatic refractor, and a 6-inch f/15 Maksutov reflector.

My testing showed all three scopes performed similarly, so the comments in general apply to all. My initial views came during the daytime, and they impressed me. When I scanned a field of view with objects at the same distance, the entire field was in focus, implying little, if any, field curvature. Using conveniently placed local landmarks, I found both rectilinear and angular distortion to be well controlled, meaning parallel lines remained parallel and objects kept their proportions throughout the field.

Because of the 20 millimeters of eye relief, the eyepieces were comfortable to view through, and with proper use of the eye guard, I experienced no blackout. Through the years, I've found some eyepieces to be warm (yellow bias) and others cool (blue bias). Here, each DeLite eyepiece particularly impressed me by its decidedly neutral color tone.

As I get older, I'm losing some of my visual accommodation. This difficult admission ironically makes it easier to check if eyepieces are parfocal (whether each holds focus without touching the scope's focuser). After establishing critical focus with the 7mm, I found that I could interchange eyepieces without touching focus. The DeLites are a good choice for use in daytime spotting scopes.

Paul Delechiaie designed the DeLite eyepiece line for Tele Vue Optics. His previous credits include the company's popular Ethos and Delos eyepiece lines. COURTESY TELE VUE OPTICS

Under the sky

At night, contrast was superb, enabling me to make out fine detail within the planetary bands of Saturn. And in the rings, the Cassini Division was obvious through the two smaller scopes. The eyepieces showed no sign of scattered light or ghost images, and transmission was quite good. Also, I noted no glare or internal reflections. Although I tend to prefer using single eyepieces to achieve desired magnifications, that's not always possible. So, it was good to learn that these eyepieces worked well with Barlow lenses.

I then moved to other targets. Through the 6-inch, the gold and blue of Albireo (Beta [β] Cygni) simply popped. Through the 18-inch, the Hercules Cluster (M13) was a jellyfish of suns against a deep-black background, and stars were pinpoint out to the edge of the field.

Staying with the big eye, the Ring Nebula (M57) was a frosted doughnut, nicely showing striations in the center with barred spiral galaxy IC 1296 a fairly easy catch off to the side. The Blinking Planetary (NGC 6826) was also a treat. Distinctly bluish-green in color, both the inner and outer shells were well defined.

If you've never seen planetary nebula NGC 7027 in a large scope, I highly recommend it. Viewing through the 18.2mm DeLite eyepiece, the object appeared small, blue, and twin-lobed, somewhat reminiscent of the Little Dumbbell Nebula (M76), although the emphasis was on the lobes rather than the center.

Finally, I took the time to check the contrast with the Fetus Nebula (NGC 7008). With a bright star just off the edge of this planetary nebula, its large size and low surface brightness can make it difficult to pick out the distinctive shape, but it was in clear view through the DeLites.

Comparing sizes

These are excellent eyepieces. But which one did I prefer? I found that my favorite eyepiece depended greatly on the telescope I used it in. Overall, each DeLite performed similarly, so I matched magnification to sky conditions. I typically wound up using between 100x and 200x for a given telescope. In the two short focal length scopes, I preferred the shortest focal length eyepiece and vice versa.

Tele Vue lists the field stops for each eyepiece as 19.1mm (for the 18.2mm DeLite), 11.7mm (for the 11mm), and 7.5mm (for the 7mm). This is important if you want to find the true field of view (in degrees). For any eyepiece/telescope combination, divide the field stop diameter by the focal length of the telescope (in millimeters) and multiply the result by 57.3. So, an 8-inch f/10 Schmidt-Cassegrain telescope that has a focal length of 2000mm will yield true fields of view around 0.55°, 0.34°, and 0.21° for the 18.2mm, 11mm, and 7mm eyepieces, respectively.

Bottom line

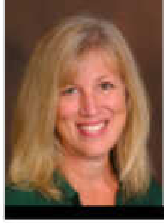
With the departure of the Tele Vue Radian line — a lightweight eyepiece with tons of eye relief — many observers were hoping for something to fill that void. With excellent contrast, great eye relief, and a decent apparent field of view, the DeLites do just that. The only caveat is that they are currently available in only three focal lengths.

While the range is well chosen for an initial offering, users of shorter focal length scopes will need to use a Barlow lens if they want to obtain high magnification. However, I'd be surprised if the company doesn't address this down the road.

Tele Vue has once again created a line of all-around excellent eyepieces, good for both planetary and deep-sky work. Selling points are long eye relief, a small and light design, and the relatively inexpensive cost. The DeLite line should be on your must-view-through list of eyepieces at the next star party.

PRODUCT INFORMATION

Tele Vue DeLite eyepiece line
Focal lengths: 7mm, 11mm, and 18.2mm
Eye relief: 20mm
Apparent field of view: 62°
Price: $250 each
Contact: Tele Vue Optics
32 Elkay Drive
Chester, NY 10918
[t] 845.469.4551
[w] www.televue.com



ASTRO**SKETCHING**

BY ERIKA RIX

Edgy stars

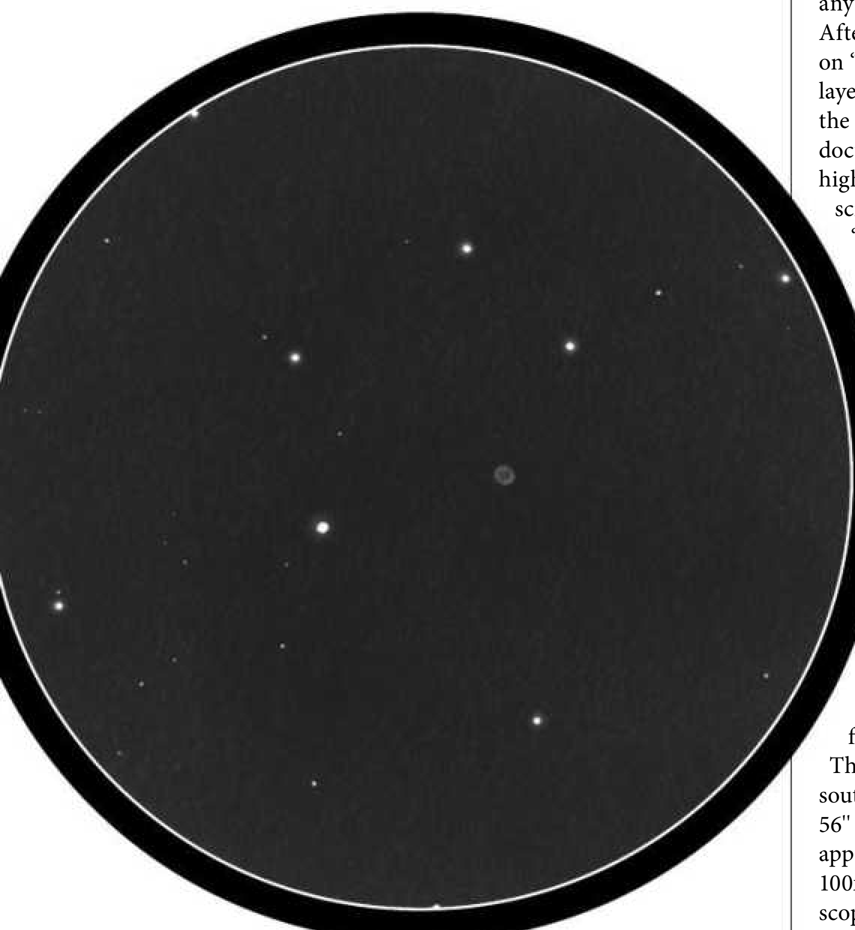
Regardless of the effort I put into drawing perfectly round stars, every jagged imperfection reveals itself once I scan the sketch and display it on my computer monitor. In a previous issue, I explained how to remove the rough edges around individual stars with a cloning tool found in image-processing software. Now, I'd like to share a technique that tackles the entire star field in one swoop so that you can tidy even open star clusters like NGC 1502 with ease.

Near the Giraffe's tail in the constellation Camelopardalis, a 2.5°-long chain of stars commonly known as Kemble's Cascade tumbles from the northwest to the southeast and splashes into NGC 1502. Measuring 8' across, the cluster shines at magnitude 6.9 with Struve 485, a 7th-magnitude double star, glowing brilliantly at its heart. Several members, including Struve 484, pair up to resemble a runway spanning east to west through the length of the cluster. Through a 4-inch telescope, nearly two dozen of its stars form a glistening triangular shape at 125x. With larger instruments, this striking cluster appears bright and compact with a concentration of over 40 stars.

For both observations, the author used a 4-inch f/9.8 refractor on an equatorial mount and oriented the sketches so that north is at the top and west to the right. She used white printer paper with 8B, 2B, and 2H graphite pencils, a blending stump, and a kneaded eraser. She observed NGC 1502 with an 8mm eyepiece for a magnification of 125x. ALL SKETCHES BY ERIKA RIX

I used Adobe Photoshop after scanning my sketch, but any similar software will do. After opening the file, I clicked on "Layer" and then "Duplicate layer" to create another copy of the sketch within the same document. With the top layer highlighted, I selected "Dust & scratches" (within the "Filter," "Noise," options) and adjusted "Radius" and "Threshold" until I found the right combination to soften the stars without losing the faintest ones in the process. I adjusted the "Opacity" of the top layer to bring forward the sharper details of the original underlying sketch.

Next, I'll use the sketch of the Oyster Nebula (NGC 1501) to demonstrate the process for other types of objects. This planetary nebula lies 1.5° south of NGC 1502 and spans 56" by 48" at magnitude 11.5. It appears as a faint, soft disk at 100x through a 4-inch telescope. Oxygen-III and ultra-high contrast filters will improve the ring's appearance. Viewing through an 8-inch telescope reveals a brightened southwest rim and two knots on the northeast rim. With increased aperture, the darker central region appears mottled, and you may be treated to a glimpse of its 14th-magnitude central star.



The author observed NGC 1501 with a 12mm eyepiece for a magnification of 83x. She used an Oxygen-III filter to add contrast to the planetary nebula.

I used the same Photoshop technique in my sketch of the Oyster Nebula as I did for NGC 1502. In this instance, the "Radius" and "Threshold" adjustments improved the soft appearance of NGC 1501. However, if you wish to leave the nebula untouched and only soften the stars around it, you need to add a mask to the duplicated layer. To achieve this, click on the "Add a layer mask" icon in the "Layers" panel. You can then use the "Brush" tool to remove the nebula from the duplicated sketch and expose the original version below.

Questions or suggestions? Please feel free to contact me at erikarix1@gmail.com.

NEW PRODUCTS

Attention, manufacturers: To submit a product for this page, email **mbakich@astronomy.com**.

6-inch astrograph

Orion Telescopes & Binoculars
Watsonville, California

Orion's 6" f/9 Ritchey-Chrétien Astrograph Telescope contains hyperbolic mirrors with 96 percent reflectivity. The unit has a rotatable 2" dual-speed Crayford focuser. It features two dovetail finder scope bases and includes one 2" and two 1" focus extension rings.

Price: $499.99
[t] 800.447.1001
[w] www.telescope.com

3-D eyepieces

Denkmeier Optical
Hauppauge, New York

Denkmeier's L-O-A 21 allows you to see the heavens in 3-D. The eyepieces create six levels of depth in each view. You can choose to have your target in the center of the field of view appear either closer or farther than other visible objects.

Price: $599
[t] 410.208.6014
[w] www.denkmeier.com

Planisphere

Celestial Teapot Designs
Buda, Texas

Celestial Teapot Designs' Messier Observer's Planisphere contains the Messier objects with data and finder charts to help you locate these deep-sky objects. It is 18 inches (46 centimeters) in diameter and for use in the Northern Hemisphere.

Price: $29.99
[t] 817.729.7254
[w] www.messierplanisphere.com

3.5mm eyepiece

Vixen Optics
San Clemente, California

Vixen's SSW 3.5mm Ultra Wide 1¼" Eyepiece features an 83° apparent field of view. The fully multicoated optics provides a light transmission of more than 99.5 percent, and eye relief is 13 millimeters. The eyepiece has a hexagonal barrel, anodized aluminum body, and retractable rubber eye-cup.

Price: $349
[t] 949.429.6363
[w] www.vixenoptics.com

SEE REPORTS ON 350+ PRODUCTS AT **www.Astronomy.com/equipment.**

COSMICIMAGING

BY ADAM BLOCK

Concentric contemplation

Astrophotography is a complex subject with facets that are tedious and technical as well as subtle and sublime. In this article, I would like to steer clear of the technical side of things and instead consider this kind of photography as an art form that permits expansive degrees of freedom in creative expression.

In the course of processing an image, I find myself deconstructing it into elements that are beautiful even when extracted from the whole. Details, colors, patterns, and even conceptual elements all play a role in the final result. Some objects are captivating not because of their visual appeal, but instead for what they represent.

For example, a quasar billions of light-years away — but showing up as just a few activated pixels — may be as joyful as all of the colorful gas in the Orion Nebula (M42). This deconstruction is an important technique in approaching image processing because it allows you to choose the right tools to enhance particular elements. However, this compartmentalization can lead to other avenues of expression.

Some images stick in my head for years. Stefan Seip's shot of the constellation Crux, the Southern Cross (Image #1) that I first saw in 2004 is one of them. I don't remember being overwhelmed by it at the time. But it was memorable and became an unconscious inspiration for an image I created more than 10 years later.

Painting with starlight is common and can be simple to do, as the uncountable number of star-trail pictures will attest. Seip's method of "painting" captured pure star color, which is arguably the most attractive element of pinpoints of light.

My image of the Wild Duck Cluster (M11, Image #2) does something similar in a different way. I painted with starlight by pointing the telescope at a star cluster and then rotating the camera to create circular star trails. You will not get the same result if you take a picture of a star cluster and spin the image in Photoshop. The brightness of the painted starlight is much fainter because it is moving across pixels at a particular rate. In addition, many stars lie at the same distance from the center of rotation. As the light from these stars mixes, the rings formed by star trails will create a fascinating palette of colors.

This image captures a deconstructed cluster, but star color is only one aspect of it. The spacing between the rings of light emphasizes the stellar density profile of the cluster. The art shines through because the mesmerizing effect of thin concentric circles is hard to ignore. This is a kind of representational art that I find fascinating. Given time, it would be great to make a collection of photographs of different clusters to see how they differ or perhaps leave the collection unlabeled and try to figure out which image matches a particular star cluster.

If our pictures capture *Musica Universalis* (the Harmony of the Spheres), then the next time you are processing an image, consider the notes that make up the melodies of the cosmos.

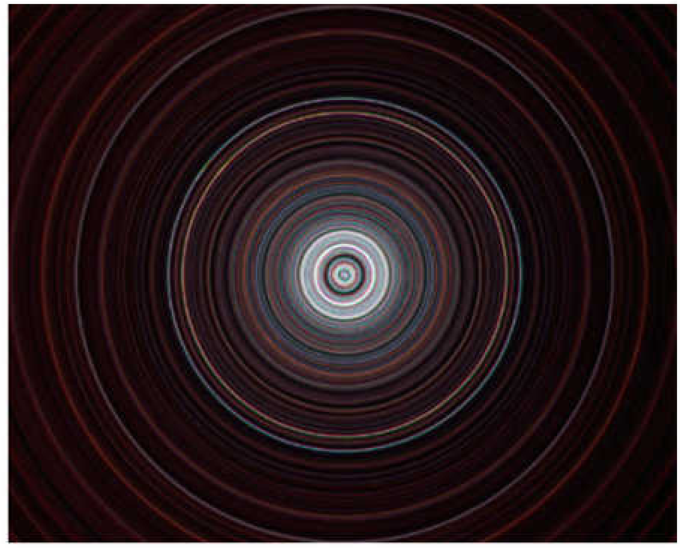


Image #2. The author created this unique view from an image he took of the Wild Duck Cluster (M11). See www.adamblockphotos.com/m11-concentric-contemplation.html for versions with and without stars. ADAM BLOCK

STEFAN SEIP/ASTROMEETING.DE

Image #1. To create this image, Stefan Seip slowly changed the focus of his camera's lens as Earth rotated. This highlighted the star colors of the constellation Crux.

FROM OUR INBOX

Thank you

I am a longtime *Astronomy* subscriber, and it is still my favorite magazine. I want to thank you for adding Jeff Hester's column "For Your Consideration." I have found these articles to be thought-provoking, educational, and extremely well written. They are right up there with "Strange Universe" and "Secret Sky." This gives me yet another reason to look forward to the next issue. Keep up the good work! — **Marty Rhodes,** Hays, Kansas

BROWSE THE "COSMIC IMAGING" ARCHIVE AND FIND VIDEO TUTORIALS AT **www.Astronomy.com/Block.**

COMING IN OUR NEXT ISSUE

Inside the new mission to Europa

After decades of canceled missions and false starts, NASA is finally headed for Carl Sagan's dream destination

New missions mine asteroid secrets

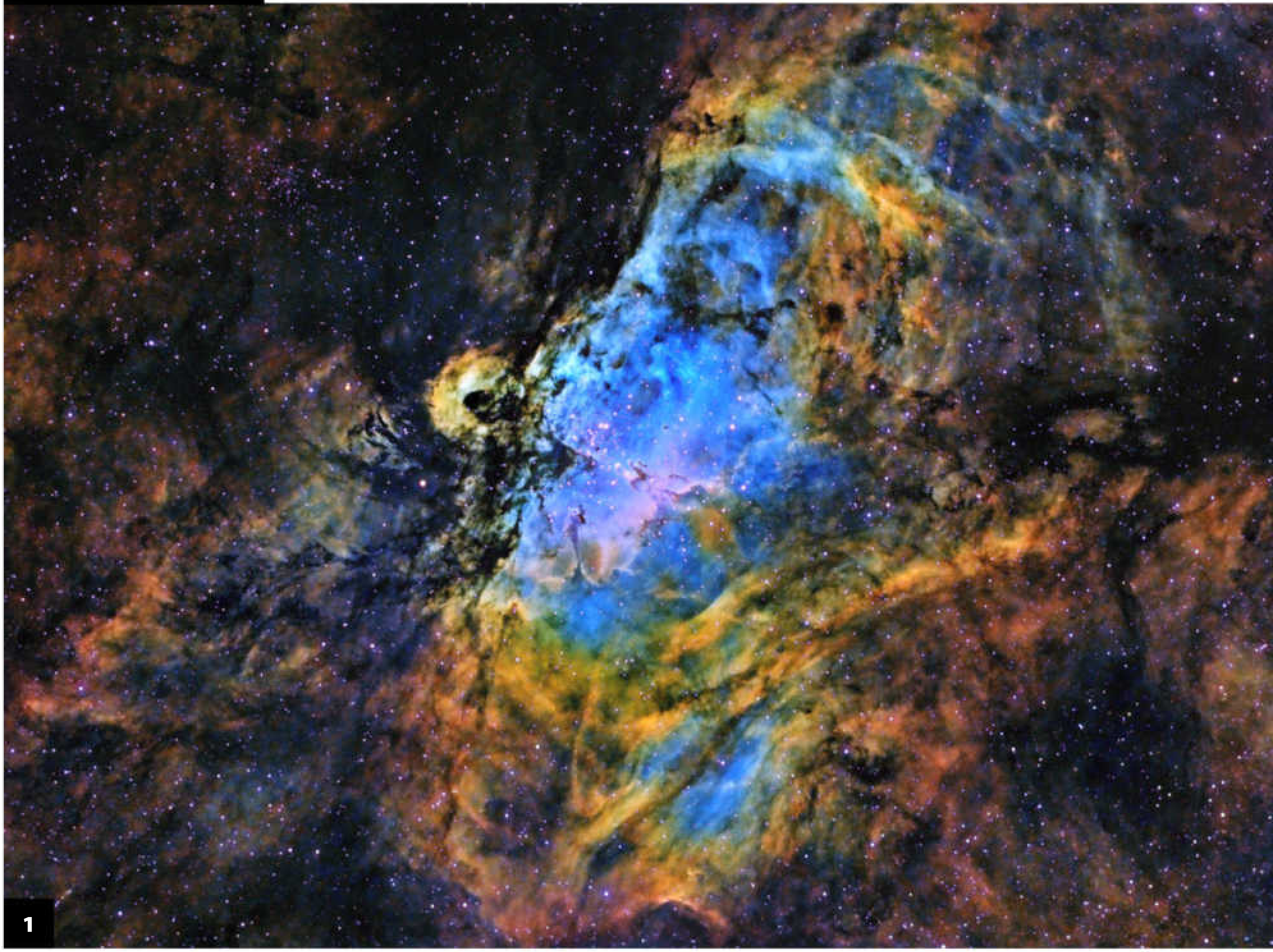
Untangling the magnetic universe

PLUS

- Celebrating Stephen Hawking's legacy
- Where is amateur astronomy heading?
- How to image Jupiter
- Sky-Watcher USA's hot new scope tested

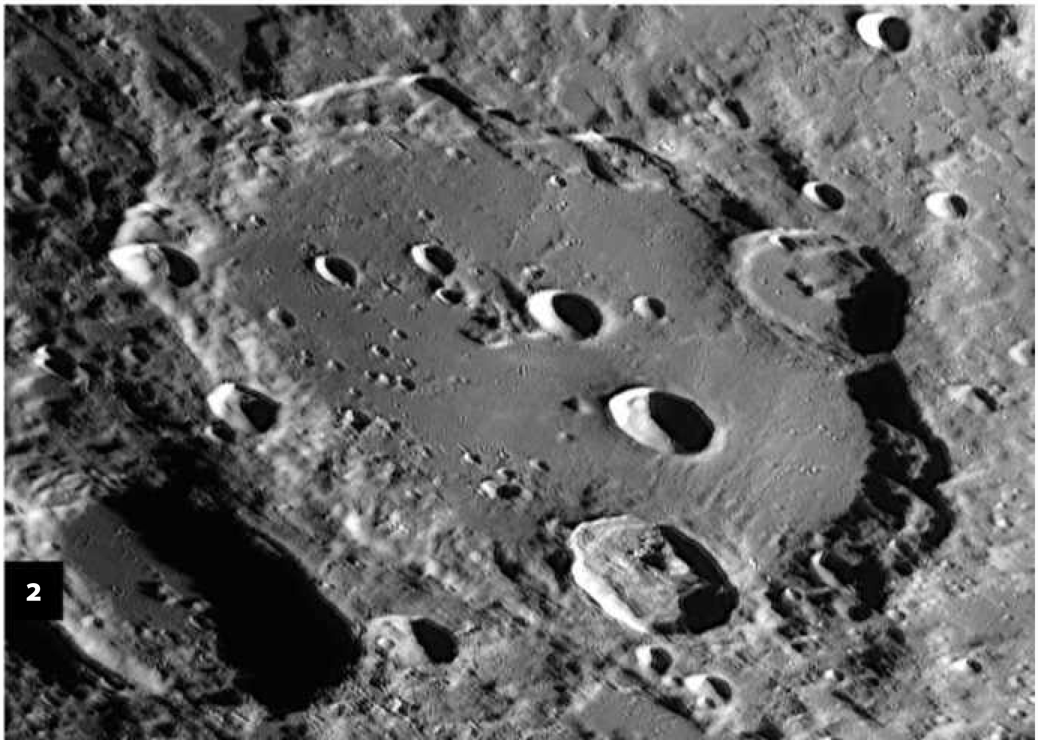
Astronomy magazine

NASA (EUROPA); AKIHIRO IKESHITA (HAYABUSA2); NASA/ESA/HUBBLE HERITAGE TEAM (STScI/AURA) (MAGNETIC UNIVERSE)

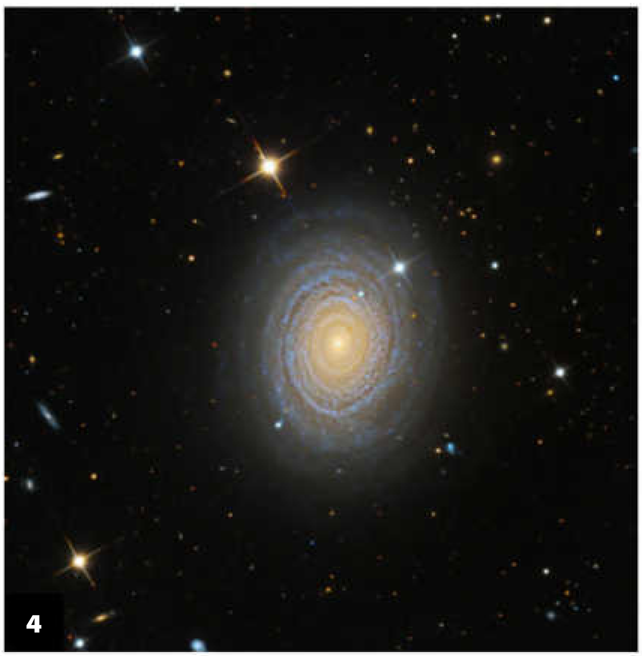


1. DWARF PILLARS
The Eagle Nebula (M16) is a region in the constellation Sagittarius that contains a star cluster and an emission nebula. This view through Hubble palette filters covers 1.78° by 1.36° of the sky. The iconic Pillars of Creation — looking tiny here — lie at the image's center. (Four-telescope, four-camera collaboration, 177 frames with a total exposure time of 32 hours)
• Colin Cooper, Terry Hancock, Kim Quick, and Gordon Wright

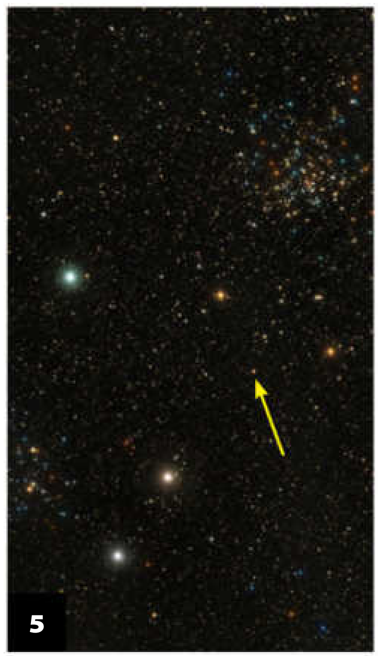
2. IMPACTS GALORE
Clavius Crater is a favorite among lunar observers because of the many craterlets of different sizes within and around it. Clavius is the third-largest crater on the Moon's nearside. It boasts a diameter of 140 miles (225 kilometers). (12-inch Meade LX200 Schmidt-Cassegrain telescope at f/18, ZWO ASI120MM CCD camera plus a red filter, taken October 23, 2015, at 2h04m UT)
• Richard Jakiel



3



4



5

6

3. MIRROR IN THE DARK
This fascinating shot of a region in the constellation Taurus combines the small reflection nebula IC 2087 (center) with the much larger dark nebula Barnard 22. Areas such as this one eventually turn into star-forming regions, which produce open clusters. (4-inch Takahashi FSQ-106 refractor, SBIG STL-11000 CCD camera, LRGB image with 10 hours total exposure) **• *Robert Fields***

4. COMPELLING CONCENTRICITY
NGC 488 is a beautiful, delicately wound spiral galaxy some 90 million light-years away in the constellation Pisces the Fish. The blue regions along the spiral arms are newly formed star clusters. (32-inch Schulman Telescope, SBIG STX-16803 CCD camera, LRGB image with exposures of 12, 5, 5, and 5 hours, respectively) **• *Adam Block/Mount Lemmon SkyCenter/University of Arizona***

5. SCARLET SURPRISE
Open cluster NGC 1528 lies to the upper right in this image, and the less-rich open cluster NGC 1545 is at the lower left. The arrow points to HIP 19931, an ultra-red carbon star. All lie in the constellation Perseus. (4-inch Sky Watcher Esprit 100ED refractor, QHYCCD QHY9M CCD camera, LRGB image with three 5-minute exposures through each filter) **• *Jaspal Chadha***

6. A SONG OF ICE AND STARS
This image captures the starry sky above Laigu Glacier at the roof of the world in Tibet. The Milky Way's central bulge is visible even with the waxing crescent Moon nearby. The reddish hue to the left is airglow, and the bright region to the right is the fading twilight above the glacier. (Canon 6D, Nikkor 14-24mm F/2.8G lens set at 14mm and f/2.8, ISO 3200, eight-part panorama, each of which was a 30-second exposure) **• *Jeff Dai***

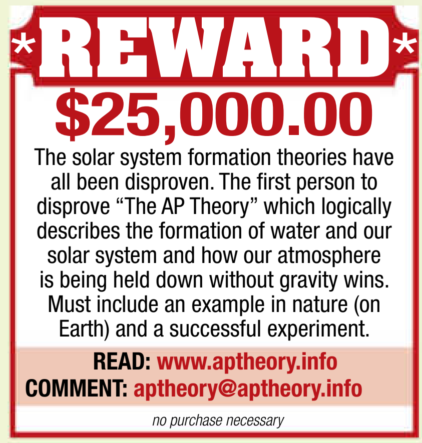
7. CATALINA CRUISING
Comet Catalina (C/2013 US 10) gives off a distinct greenish glow and sports a complex tail in this image from early October 2015. On this date it was in the southern constellation Centaurus. (12-inch Astro Systeme Austria astrograph at f/3.6, FLI ML-8300 CCD camera, LRGB image with exposures of 12, 5, 5, and 5 minutes, respectively, taken October 3, 2015, from Farm Tivoli, Namibia) • ***Gerald Rhemann***

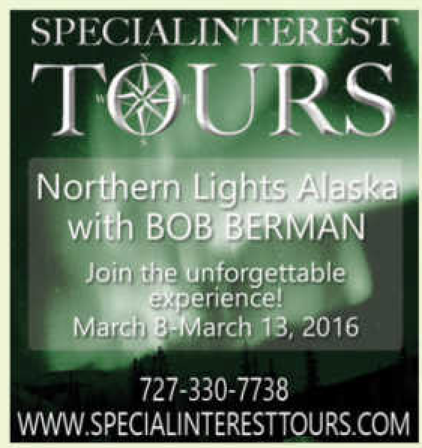
8. SURPRISE STREAK
While shooting the aurora borealis last fall, this photographer captured a Taurid meteor. Even two seconds was enough to overexpose the Moon, one day past its Last Quarter phase. (Canon 5D Mark III, Rokinon manual lens set at 14mm and f/4, ISO 1250, 2-second exposure, taken November 4, 2015, at 2:58 A.M. Alaska Time, near Palmer, Alaska) • ***Matt Skinner***

Send your images to:
Astronomy Reader Gallery, P. O. Box 1612, Waukesha, WI 53187. Please include the date and location of the image and complete photo data: telescope, camera, filters, and exposures. Submit images by email to readergallery@astronomy.com.

INDEX *of* ADVERTISERS

The Advertiser Index is provided as a service to *Astronomy* magazine readers. The magazine is not responsible for omissions or for typographical errors in names or page numbers.





BREAK THROUGH

Through a lens, darkly

The Hubble Space Telescope has gone deep before, but never has it plumbed the universe's depths as it is doing in the three-year Frontier Fields program. Hubble has targeted six massive galaxy clusters, each of which acts as a gravitational lens to amplify, smear, and stretch the faint light from background objects. The program already has discovered some 250 small galaxies from when the cosmos was just 600–900 million years old. This foreground cluster, cataloged as MACS J0717.5+3745, lies 5.4 billion light-years away. It is one of the most massive clusters known and the largest identified gravitational lens. NASA/ESA/THE HST FRONTIER FIELDS TEAM (STScI)

MARTIN GEORGE describes the solar system's changing landscape as it appears in Earth's southern sky.

May 2016: Mars shines big and bright

As evening twilight deepens in early May, **Jupiter** rules the northeastern sky. The giant planet lies between the rear legs of Leo the Lion, nearly 15° to the right of that constellation's brightest star, 1st-magnitude Regulus. Shining at magnitude –2.3, Jupiter appears far brighter than any other object in the early evening sky.

The gas giant climbs halfway to the zenith by mid-evening when it is perfectly placed for viewing through a telescope. Any scope reveals Jupiter's 41"-diameter disk (it shrinks to 37" across by late May) featuring a bright equatorial zone bordered by a darker belt on each side. A series of alternating zones and belts shows up under excellent conditions. Also keep an eye out for four bright moons, which orbit in the planet's equatorial plane.

Shortly after the sky grows completely dark, two more bright planets appear low in the east. **Mars** rises first and, at magnitude –1.5, nearly matches Jupiter's brilliance. You won't mistake it for its similarly colored ancient rival, Antares, which lies just 5° to the planet's right, because Mars shines 10 times brighter.

The Red Planet moves westward relative to the background stars this month, cutting across the entirety of northern Scorpius the Scorpion. It passes between the 2nd-magnitude stars Beta (β) and Delta (δ) Scorpii on May 19. Just three days later, on the 22nd, Mars reaches opposition and peak visibility. It then shines at magnitude –2.1, equaling giant Jupiter. The planet crosses into Libra in May's final days, when it lies closest to Earth. The ruddy world then spans 18.6", the biggest it has been since 2005. Delight in viewing Mars' dusky surface markings and the bright polar regions; currently, the planet's north pole tilts slightly in our direction.

Not long after Mars appears, **Saturn** comes into view. The gas giant resides in Ophiuchus the Serpent-bearer all month, several degrees below Antares as they climb higher in the eastern evening sky. Saturn brightens from magnitude 0.2 to 0.0 during May as it nears its early June opposition.

Be sure to take some time to explore Saturn through a telescope. Any instrument reveals the splendid ring system, which spans 42" and tilts 26° to our line of sight in mid-May. The planet's brightest moon, 8th-magnitude Titan, also shows up easily. A 10-centimeter or larger instrument will bring in the 10th-magnitude trio of Tethys, Dione, and Rhea.

Mercury comes into view twice this month. On May 9, the innermost planet passes directly between the Sun and Earth. Observers who watch this transit through a telescope — which must be properly equipped with a safe solar filter — will see the planet's tiny disk silhouetted against the Sun's bright face. People in South America and southern Africa can view at least part of this 7.5-hour transit.

Just a couple of weeks later, Mercury reappears before dawn. By May 31, the planet climbs 10° high in the east-northeast an hour before sunrise. A telescope then shows a 9"-diameter disk exhibiting a beautiful crescent shape.

Venus lies too close to the Sun to see during May. It passes behind our star in June and will return to view after sunset in July.

The **Eta Aquariid meteor shower**, the finest visible from the Southern Hemisphere, peaks May 5. With New Moon arriving just a day later, conditions should be nearly perfect if the weather cooperates. Observers under a dark sky can expect to see up to 40 meteors per hour before twilight starts to paint the sky.

The starry sky

If you look closely at a star chart, the borders of many constellations look rather complex. You might expect it would be a daunting challenge to calculate how much area each of these 88 patterns occupies. It is possible, of course, and astronomers know precisely how the constellations divvy up the celestial sphere's total of 41,252.96 square degrees.

Members of the International Astronomical Union (IAU) agreed on the borders of the constellations at its general assembly in 1928, though the IAU didn't publish the results until 1930. Most astronomers consider the latter year to be the one in which the borders took effect.

The May evening sky offers good views of the two largest constellations: Hydra the Water Snake ranks number one followed by Virgo the Maiden. Hydra covers 1,303 square degrees while Virgo comes in close behind at 1,294 square degrees. Interestingly, the two share a border for a short distance east of Corvus.

We have a splendid view of Hydra because nearly all of the constellation lies south of the celestial equator. Only Hydra's easily recognizable head extends north of the equator, to a declination of about 7°. From the head, trace the Water Snake's relatively faint stars as they slither above Sextans, Crater, Corvus, and Virgo. The body ends adjacent to the constellation Libra. Hydra's brightest star, ruddy 2nd-magnitude Alphard, lies to the head's upper right.

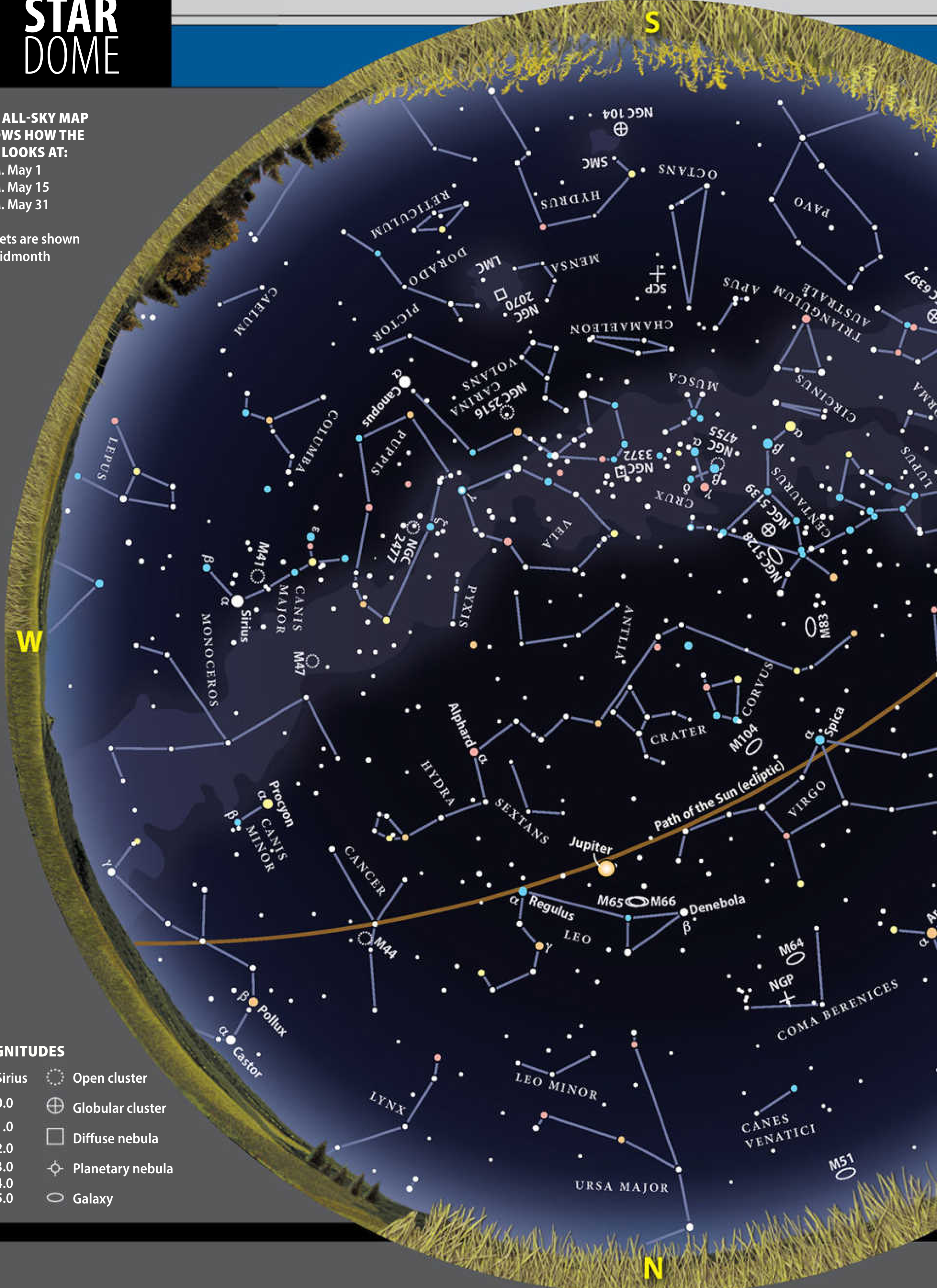
The evening sky also delivers a nice view of the constellation at the other extreme: Crux the Cross. It covers only 68 square degrees, so the Water Snake could swallow 19 Crosses. Still, 350 Full Moons could fit inside Crux!

Although the May evening sky holds the two largest constellations and the tiniest, the second-smallest one after Crux doesn't appear until after midnight. The dim constellation Equuleus the Little Horse lies east of the more conspicuous Delphinus the Dolphin. With an area of only 72 square degrees, Equuleus barely beats out Crux. It's tricky to identify because its brightest star, Alpha (α) Equulei, glows at magnitude 3.9. The Cross boasts a half-dozen that exceed this brightness.

STAR DOME

THE ALL-SKY MAP SHOWS HOW THE SKY LOOKS AT:
9 P.M. May 1
8 P.M. May 15
7 P.M. May 31

Planets are shown at midmonth



MAGNITUDES

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

HOW TO USE THIS MAP: This map portrays the sky as seen near 30° south latitude. Located inside the border are the four directions: north, south, east, and west. To find stars, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

STAR COLORS: Stars' true colors depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white without optical aid.

Illustrations by *Astronomy*: Roen Kelly

MAY 2016

Calendar of events

2 The Moon passes 1.7° north of Neptune, 11h UT

5 The Moon passes 2° south of Uranus, 3h UT

Eta Aquariid meteor shower peaks

6 The Moon is at perigee (357,827 kilometers from Earth), 4h13m UT

New Moon occurs at 19h30m UT

8 The Moon passes 0.5° north of Aldebaran, 9h UT

9 Mercury is in inferior conjunction, 15h UT; transits the Sun

Jupiter is stationary, 23h UT

13 First Quarter Moon occurs at 17h02m UT

15 The Moon passes 2° south of Jupiter, 10h UT

18 The Moon is at apogee (405,933 kilometers from Earth), 22h06m UT

21 The Moon passes 6° north of Mars, 20h UT

Full Moon occurs at 21h14m UT

Mercury is stationary, 22h UT

22 Mars is at opposition, 11h UT

The Moon passes 3° north of Saturn, 22h UT

23 Asteroid Vesta is in conjunction with the Sun, 19h UT

29 Last Quarter Moon occurs at 12h12m UT

Asteroid Iris is at opposition, 18h UT

The Moon passes 1.4° north of Neptune, 19h UT

30 Mars comes closest to Earth (75.3 million kilometers away), 22h UT

BEGINNERS: WATCH A VIDEO ABOUT HOW TO READ A STAR CHART AT **www.Astronomy.com/starchart.**